AGGREGATE SURFACE TEXTURE INFLUENCES
ON ASPHALTIC CONCRETE SKID RESISTANCE

By

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ABSTRACT

For asphaltic concrete surface courses, the surface texture of the exposed coarse aggregate is the key factor influencing the skid resistance performance of the pavement. With time, this surface texture is altered by the dynamic, interactive processes of polishing, wear or abrasion and weathering. In this study, four types of aggregate which are available in Ontario - traprock, limestone, steel slag and blast furnace slag - were subjected to these processes in order to evaluate their surface texture characteristics. The study was completed in terms of both quantitative analyses of laboratory samples and qualitative analyses of field and laboratory samples. Two major aspects were surface texture evaluation using the scanning electron microscopy, and the simulation of weathering influences on skid resistance. Both chemical and x-ray diffraction analyses were completed to support the evaluation.

From the study, two new concepts - positive and negative rejuvenating processes and Potential Rejuvenating Value (PRV) - were developed. Steel slag, with a relatively high PSV, low AAV and potential negative rejuvenation was found to be the most desirable aggregate in terms of skid resistance performance.

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Finally, this thesis is dedicated to Mary who has touched and brightened his life.

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1 INTRODUCTION

1.1 SKID RESISTANCE

Skid resistance can be defined as the frictional resistance which occurs during the interaction between the tires of a moving vehicle and the pavement surface. The importance of good resistance against skidding on roads and highways was soon recognized with the growing use of cars as a mode of transportation. As early as 1920, it was becoming apparent that an increasing number of car accidents were related to skidding (1, 2). Skidding occurs when the brakes are applied to slow or stop a moving vehicle, but the vehicle continues to move forward with locked wheels, essentially out of control. Studies conducted in Europe and North America indicate that skidding related accidents may represent up to 40 percent of total car accidents (3, 4). The proportion of skidding accidents, of course, depends on factors such as location, road condition, environment and season. It is very clear that skidding accidents occur much more frequently during wet road conditions, as indicated by caution signs on many highways showing potential wet road hazards.

With the wide use of cars, increasing overall traffic and improvements to produce high speed cars, skid resistance has become a critical factor to today's highway safety. Important controllable design factors for providing adequate skid resistance include tire condition and pavement surface.

The flexible pavement (asphaltic concrete) surface is the key factor effecting skid resistance performance that is of concern to this study. This is also a general area of concern to the pavement designers, since the frictional resistance between the tire and the road depends on the surface characteristics of the road itself, particularly the exposed coarse aggregate. The selection of suitable coarse aggregates for a pavement surface is very important to provide good skid resistance, since there is a wide range in their skid resistant properties.

Another related factor which influences the skid resistance performance of the road is the coupled polishing-wear rejuvenation mechanism (weathering) which occurs at the pavement surface. This is a dynamic process, in which physical changes at the pavement surface can affect the skid resistance performance of the road.

It should be noted that while this study deals with asphaltic concrete surface course skid resistance, many of the concepts are important to portland cement concrete pavements.

1.2 SURFACE TEXTURE

Microtexture and macrotexture are the two scales used to describe the surface texture of asphaltic concrete surface courses. Microtexture usually refers to the fine size texture, which makes the coarse aggregate feel smooth to the touch. On the other hand, macrotexture refers to the projections of the aggregate above the matrix. It also refers to the angularity of the particles, and the voids and pitting of the pavement surface.

There are various methods available to examine the surface texture of pavements. The macrotexture can be obtained by the sand patch method or putty/grease method (5). Evaluation of aggregate microtexture can be based on stereo photographs using a scanning electron microscope. This is a powerful method to qualitatively examine the microtexture of aggregates.

Macrotexture is usually considered to be the texture scale which influences skid resistance performance at high speeds. When the road is wet, it is necessary to provide drainage for the water film during the interaction between tire and road. For the high speed case, drainage must occur very quickly, which requires the macrotexture drainage paths. On the other hand, microtexture is related to the skid resistance performance at lower speeds.

The concept of providing surface texture, as part of the pavement design, is very important to maintain good skid resistance performance. Furthermore, the weathering which occurs at the pavement surface directly effects both the microtexture and macrotexture, hence it effects the skid resistance of the asphaltic concrete surface course.

1.3 MECHANISM OF SKID RESISTANCE

The provision of skid resistance is a dynamic process which occurs at the surface of the pavement. Basically, it consists of three interacting mechanisms: the polishing of the aggregate, the wear or abrasion of the aggregate and the surface weathering.

The polishing of aggregates refers to changes in the aggregate surface microtexture. It involves smoothing the aggregate surface which can result in a highly polished, glassy surface with a minimal loss of aggregate material (i.e., macrotexture). Since polishing reduces the available microtexture of the aggregate, consequently it effects the performance of the road against skidding, especially for low speed traffic during wet conditions. There are various laboratory and field methods to measure the polishing of aggregates. One common way to measure polishing is by using the British portable pendulum test (BS 812, Reference 6). The reported value from this test is called the Polished Stone Value (PSV). This method was used in the testing program.

Unlike polishing, the process of wear or abrasion by traffic involves a fair loss of aggregate material. Hence, the process of grinding away the aggregate is far larger in scale than the polishing process. Generally, wear or abrasion occurs with the presence of larger "abrasive" material sizes on the road surface coupled with tire action. Dirt or soil, stones and winter salt are the main abrasives involved.

If polishing refers to the smoothing of aggregate microtexture, wear or abrasion refers to the loss of the macrotexture of the road surface. However, this process also influences the microtexture of the road. If an aggregate's macrotexture is being grinded away, the microtexture definitely will also change. Its changes mainly depend on the physical properties of the aggregate.

One way to measure the wear or abrasion of aggregates is by using an abrasion machine. A suitable abrasion method has been developed in Great Britain (BS 812, Reference 6). This abrasion test results in a value which is called the Aggregate Abrasion Value (AAV). Basically, it is a measure of the aggregate's weight loss when subjected to a simulated abrasion process. This method was used in the testing program.

Finally, weathering is another mechanism which can effect the skid resistance performance of the road. Unlike the polishing and abrasion of the aggregate, the weathering process has not been considered as extensively. Therefore, the weathering process is one of the main topics of this study, which is explained in the following chapters.

2 SCOPE OF THE STUDY

2.1 THE IMPORTANCE OF SKID RESISTANCE

An ideal pavement surface should have a number of design characteristics so that it can serve its intended function during its service life. Some of these characteristics are: resistance against skidding; resistance to wear or abrasion; low noise; structural durability such as resistance to compression, break-up and rutting; economic construction; long life-time before resurfacing; and many others. A good pavement should be able to provide adequate skid resistance, especially when the road is wet. It should show a minimal reduction of skid resistance with time. Furthermore, there should be little reduction of skid resistance with increasing vehicle speed. A new road or highway usually has these characteristics. The aggregates at the surface have not experienced any traffic, wear, polishing, weathering, or other processes. However, as the traffic rolls over the new pavement, various things happen: the loadings cause compression and coarse aggregate immersion; the interaction between tires and the surface of the road causes the polishing and the abrasion of the aggregates; and the environment introduces weathering, with the help of rain, snow, heat, de-icing, sanding and salting, etc.

Considering the importance of skid resistance to road safety; the study of the nature of the exposed aggregates, the mechanisms which can change their surface characteristics and the use of different types of aggregates become very important.

2.2 PURPOSE OF THE STUDY

Skid resistance has been studied for some time; and some achievements as a result of the studies, such as skidding accident observations, the use of highway signs at potentially slippery roads, and many others have been used to improve the safety on the roads. Nevertheless, there are few aspects which still have not received adequate attention. The study of aggregates which have potential good skid resistance is an example in which there is little research contributed to this area. Because of the wide range of aggregate materials and mixes being used for highways, the study of aggregates for skid resistance in one country generally cannot be applied for its use in another country. Usually, the aggregates which are used for pavements are obtained locally, and the physical and chemical characteristics may vary from location to location.

Even within a province, which is certainly the case for Ontario, different types of aggregate are used in the asphaltic concrete mixes for highways. Therefore, there is a need in Ontario to evaluate the aggregates which are being used in asphaltic concrete mixes; and this study forms part of such an overall program for the Ontario Ministry of Transportation and Communication at McMaster University.

Basically, the purpose of the study was to evaluate four types of aggregate used in asphaltic concrete surface courses, which are available in Ontario: traprock, limestone, blast furnace slag and steel slag. The study involves two major areas of skid resistance which have not received adequate attention, particularly in Canada (and Ontario): surface texture evaluations, and weathering influences on skid resistance performance.

2.3 SURFACE TEXTURE STUDY

The surface texture of the aggregates was examined qualitatively using a Scanning Electron Microscope (SEM).

Furthermore, some surface contaminants developed during weathering process which may change the skid resistance performance of the aggregate were examined using x-ray diffraction methods (Kevex XRD on Cambridge Stereoscan SEM).

The SEM study consisted of two parts:

1. SEM study of core samples which were taken during fall of 1978 and spring of 1979 from the Highway 401 Test Sections, North of Toronto (Toronto by-pass section).
2. SEM study of simulated weathered aggregates. This study was conducted to examine any chemical and physical changes of the surface texture in relation to the process of weathering.

In general, the SEM study was completed to explain some of the major areas which are related to skid resistance studies, such as:

a. information about the nature of the exposed aggregate at the pavement surface;
b. visual information about the processes of polishing, abrasion and weathering by traffic action; and
c. information which can be used to explain the weathering process which forms the second part of the overall study.

2.4 WEATHERING STUDY

The major part of the overall study deals with the effects of the weathering process on skid resistance performance. Weathering is an important mechanism, in addition to polishing and abrasion, which is believed to influence skid resistance. The seasonal variations due to precipitation, as well as short term skid resistance variations, are examples of weathering influences on skid resistance that tend to compensate for some of the polishing action (i.e., microtexture rejuvenation). Weathering related to seasonal precipitation was examined extensively in the study.

The weathering study was conducted in the laboratory, subjecting aggregates to simulated weathering processes. The skid resistance performance was measured qualitatively by the use of British Portable Skid Tester (BS 812, Reference 6). Furthermore, the weathering processes were observed for four different solutions: distilled water, collected rainfall; synthetic rainwater; and a $CaCl_2$ solution. These simulations were performed to obtain the extreme conditions of weathering and the resulting changes in skid resistance.

3 QUALITATIVE STUDY OF AGGREGATE SURFACE TEXTURE USING PHOTOMICROGRAPHS

3.1 INTRODUCTION

In the evaluation of the skid resistance performance of an asphaltic concrete road surface, the nature of the exposed aggregates plays an important role. The aggregates' physical and chemical properties determine the degree of wearing, polishing and weathering processes of the road surface under traffic and environmental actions.

The polishing and abrasion processes of the aggregates were monitored by their PSV and AAV values. However, most of the study, including the determination of PSV and AAV of the aggregates, was performed quantitatively. Therefore, there was also a need to examine the aggregates qualitatively to determine how the processes operate in terms of scale and mechanisms involved. The SEM allows an examination of both the macrotexture and microtexture features which are usually measured by the Polished Stone Value (PSV). A qualitative measure based on judgement and visual classification has proven to be very useful. It can serve many purposes, such as providing information about the skid resistance processes, surface characteristics of the aggregates, chemical surface effects, etc.

By using the SEM, the surface texture of an aggregate can be examined at different magnifications. Furthermore, a series of photomicrographs can be obtained for the same purpose and as permanent record. Previous studies indicated that two types of microtexture should be used for any evaluation (7):

1. Primary microtexture, which is surface microtexture on the scale of 10 to 50 μm. This scale can be obtained on X500 magnification photomicrographs.
2. Secondary microtexture, which is surface microtexture on the scale of 1 to 5 μm. This scale can be obtained on X1500 to X3000 magnification photomicrographs.

The aggregates examined using the SEM were traprock, limestone, blast furnace slag and steel slag. Both polished and unpolished samples were investigated. Furthermore, following the simulated weathering of the aggregates, these aggregates were then also examined in the SEM.

3.2 SCANNING ELECTRON MICROSCOPE (SEM)

A picture of the Scanning Electron Microscope (SEM) is shown in Figure 1. Figure 2 gives a schematic diagram of the operational features of the SEM (8).

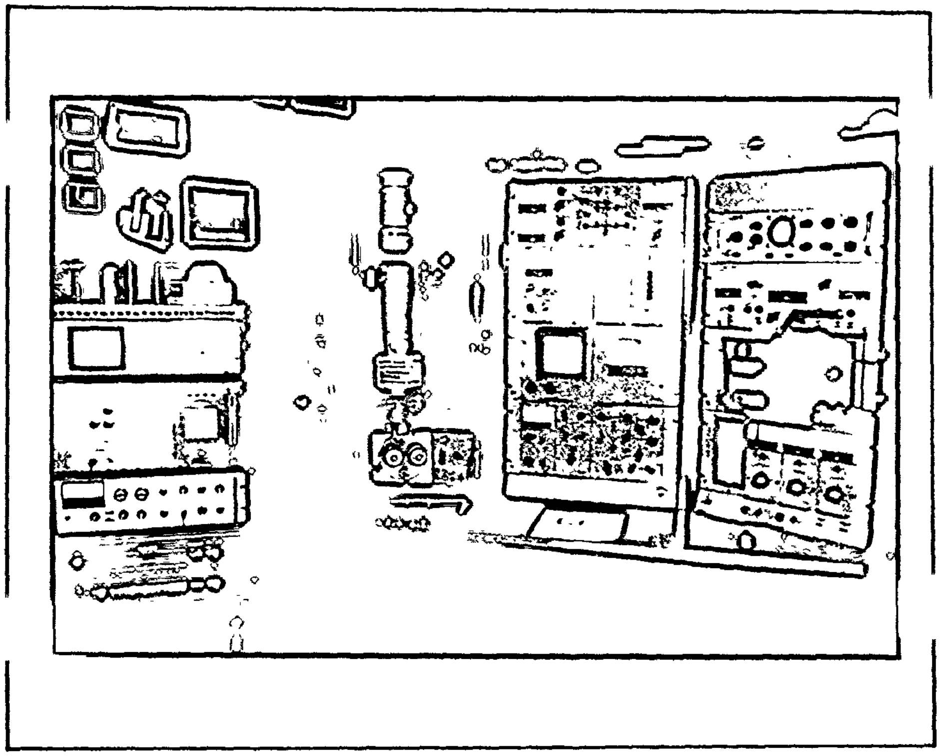


Figure 1. Scanning Electron Microscope at McMaster University, Hamilton, Ontario

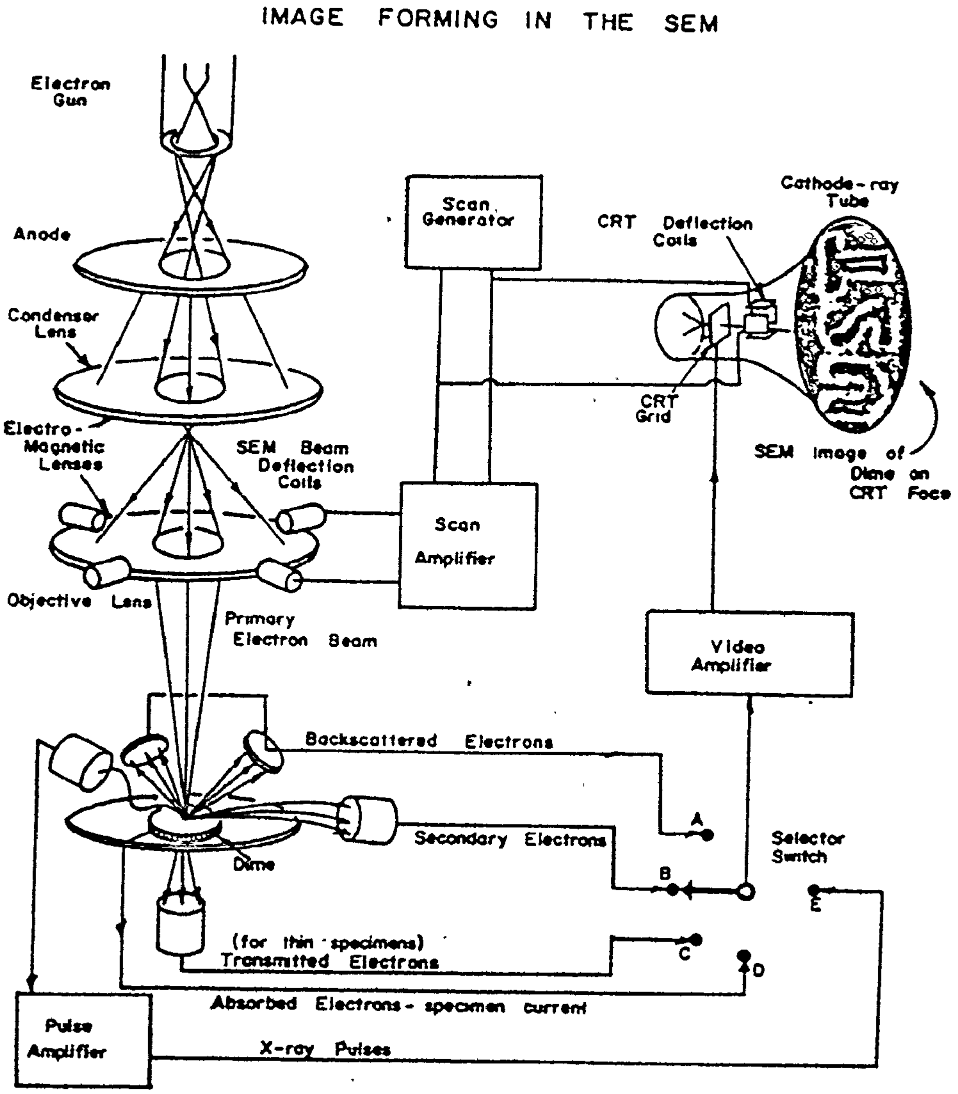


Figure 2. Schematic of the SEM(8)

Essentially, the SEM uses a fine probe of electron beams to scan over a controllable area of the surface of the specimen . The resultant emitted secondary electrons are used to modulate the brilliance of the television-type display to produce an enlarge image of the surface texture. This magnification can be varied between X20 and X50,000. To obtain photomicrographs of this magnified image, the SEM is equipped with "Polaroid" and 35 mm cameras. In this study, a Polaroid camera is used for taking both single photomicrographs and stereomicrograph pairs.

Another feature which is attached to the Cambridge Stereoscan SEM used at McMaster University, is a Kerex x-ray analyzer. It was used to detect the presence of different elements on the surface of the samples. The identification of the elements was made by comparing the value of their centroids obtained from the analyzer, with a table of x-ray emission energies. Such a table is given in Appendix A.

3.3 SAMPLE PREPARATION

Since most of the aggregates cannot conduct electricity, a special procedure was necessary to prepare samples for SEM examination. This procedure involved:

1. Cleaning of the Aggregate

   The aggregates were cleaned in an ultrasonic bath of distilled water. In some cases, the use of methyl alcohol (CH_3OH) is recommended prior to the distilled water. Then, the clean sample is dried.

2. Coating

   The clean, dry samples were then coated with thin layer of gold by evaporation coating in a vacuum chamber. The purpose of the coating is to make the aggregate surface conducting to the electron beam.

3. Storage

   To avoid oxidation of the metal coating in the atmosphere, as well as to avoid any contamination, the samples were stored in a vacuum chamber at all times.

3.4 EFFECTS OF ABRASION/WEAR ON THE SURFACE TEXTURE OF THE AGGREGATES

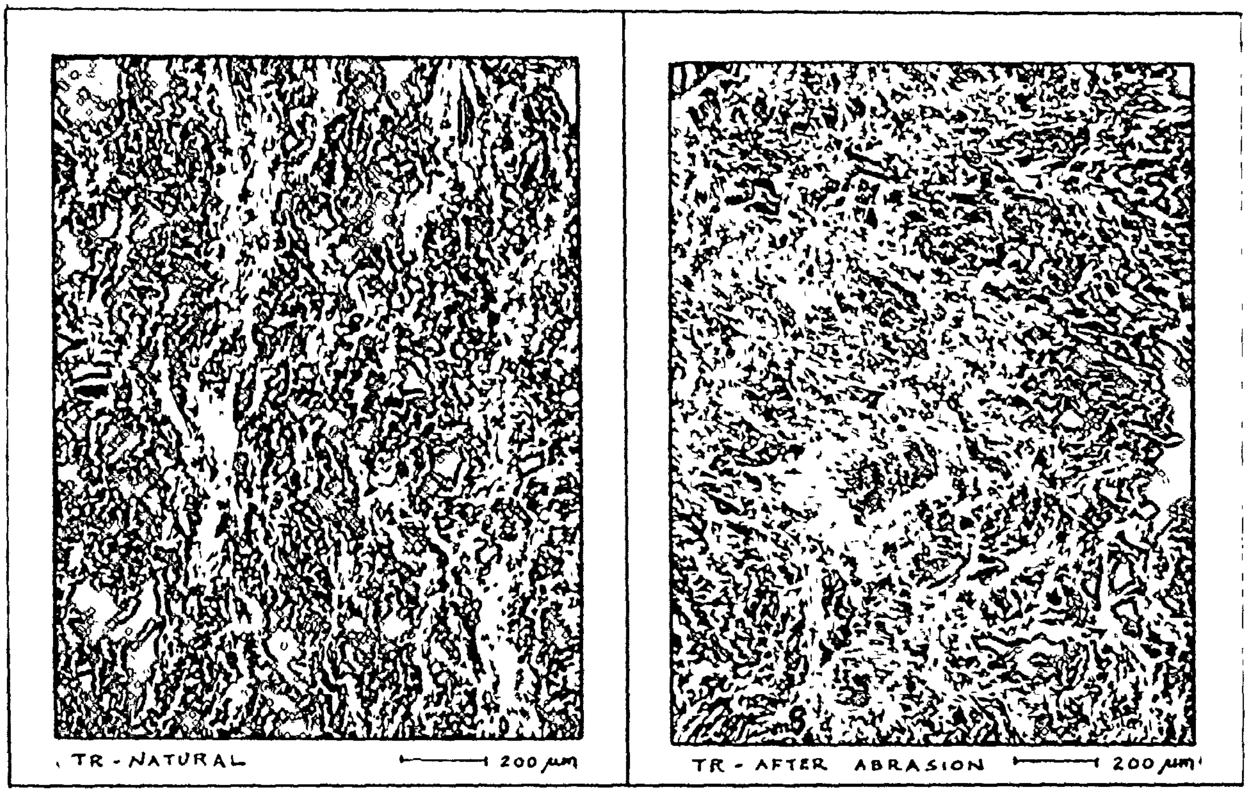
3.4.1 EVALUATION RESULTS

In this study, the abrasion or wear by traffic was simulated by using the Aggregate Abrasion Machine. A standard type of sand (Leighton Buzzard silica sand, Reference 6) was used as the abrasive in the process. Typical photomicrographs obtained from the SEM are given in Figures 3 to 10. These photomicrographs were taken at different magnifications, so that observations could be made on the surface texture of the aggregates. For comparison purposes, there are also photomicrographs which were taken of the natural aggregate surfaces before any abrasion.

The visual observations for each aggregate can be described as follows:

1. Traprock

   Figures 3 and 4 show the typical textures of the traprock, both before and after the process of abrasion. Photomicrographs were taken at about X50, X500, X1000 and X2000 magnifications. Except for the photomicrograph taken at about X2000, the process of abrasion can be seen visually. As shown in Figures 3d and 4b, some of the surface has been flattened by abrasion. Some scouring, which can be seen at these two magnifications indicate that there is significant resistance to the abrasion. This is also indicated by quantitative measure of abrasion, in which traprock has a low AAV of about 2.2 (9). At about X2000, at which secondary microtexture can be clearly seen, there is not much difference in the surface texture before and after abrasion.



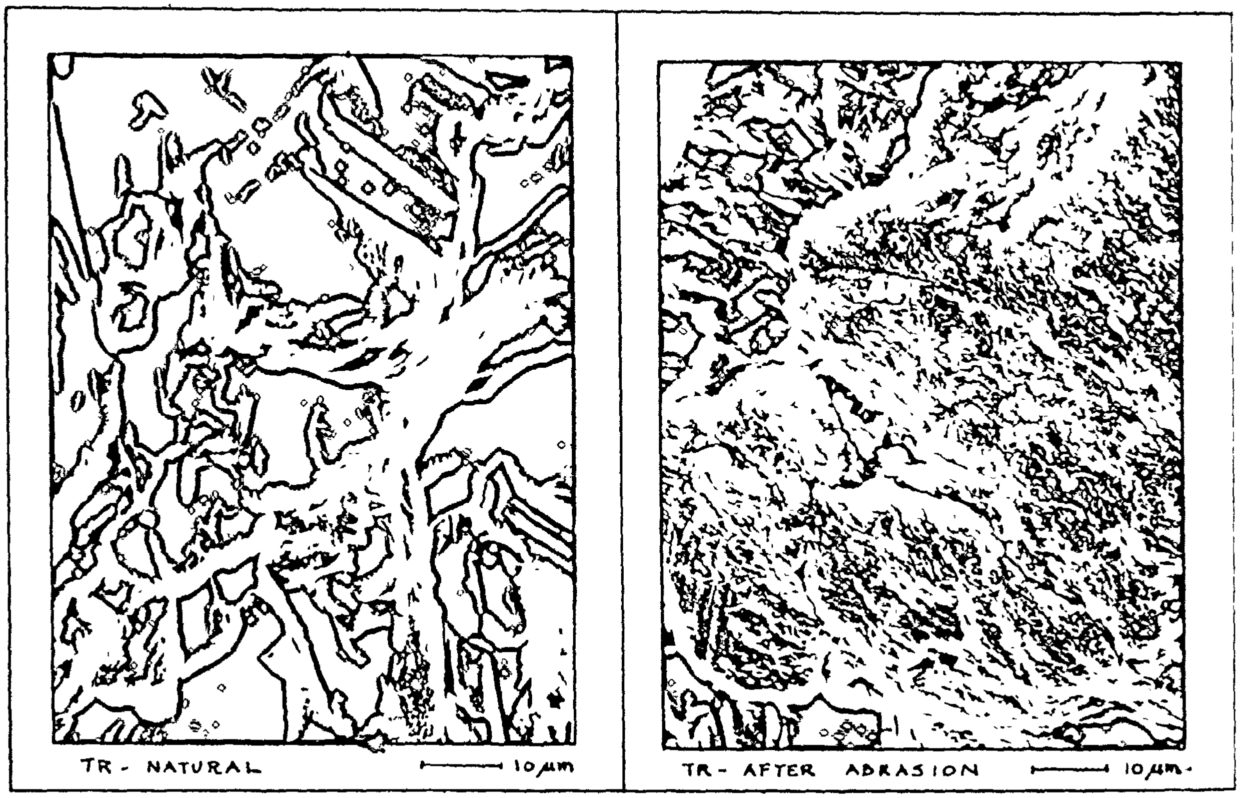
a. X58

b. X60

Figure 3. Traprock

c. X580

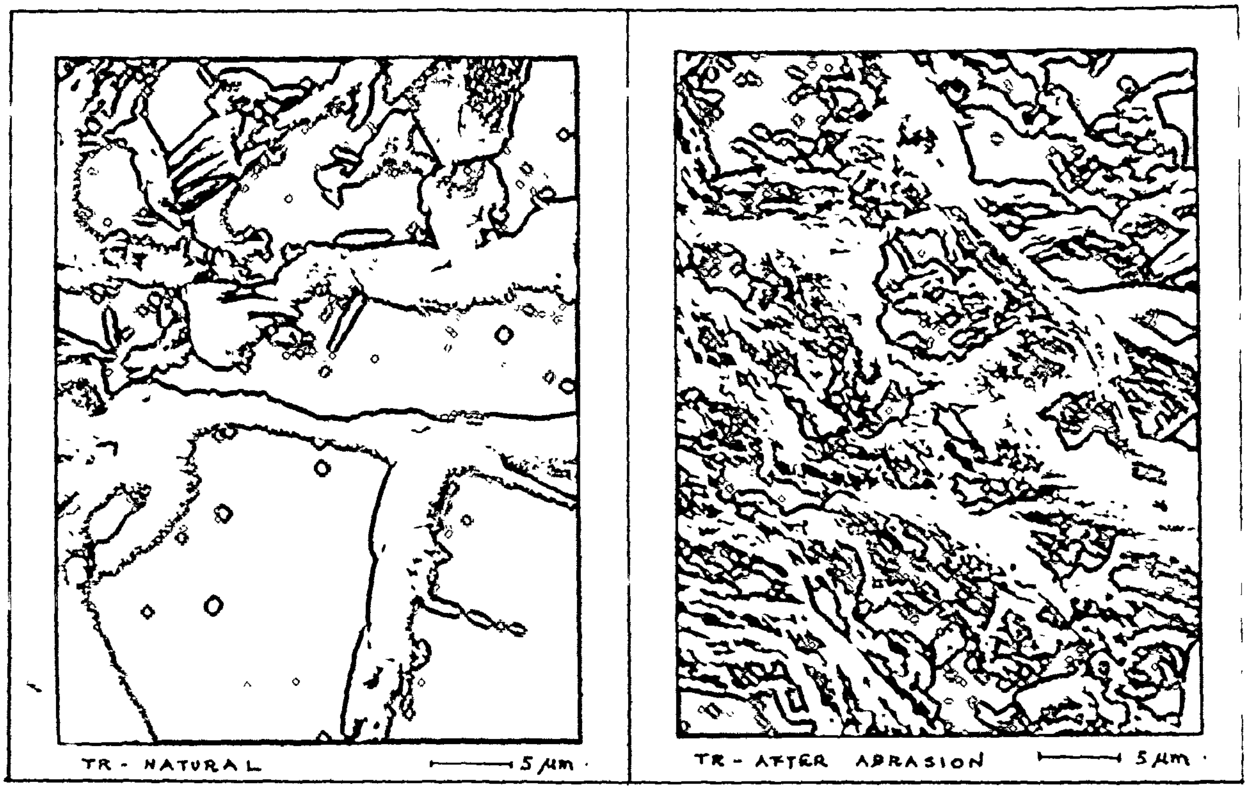
d. X525

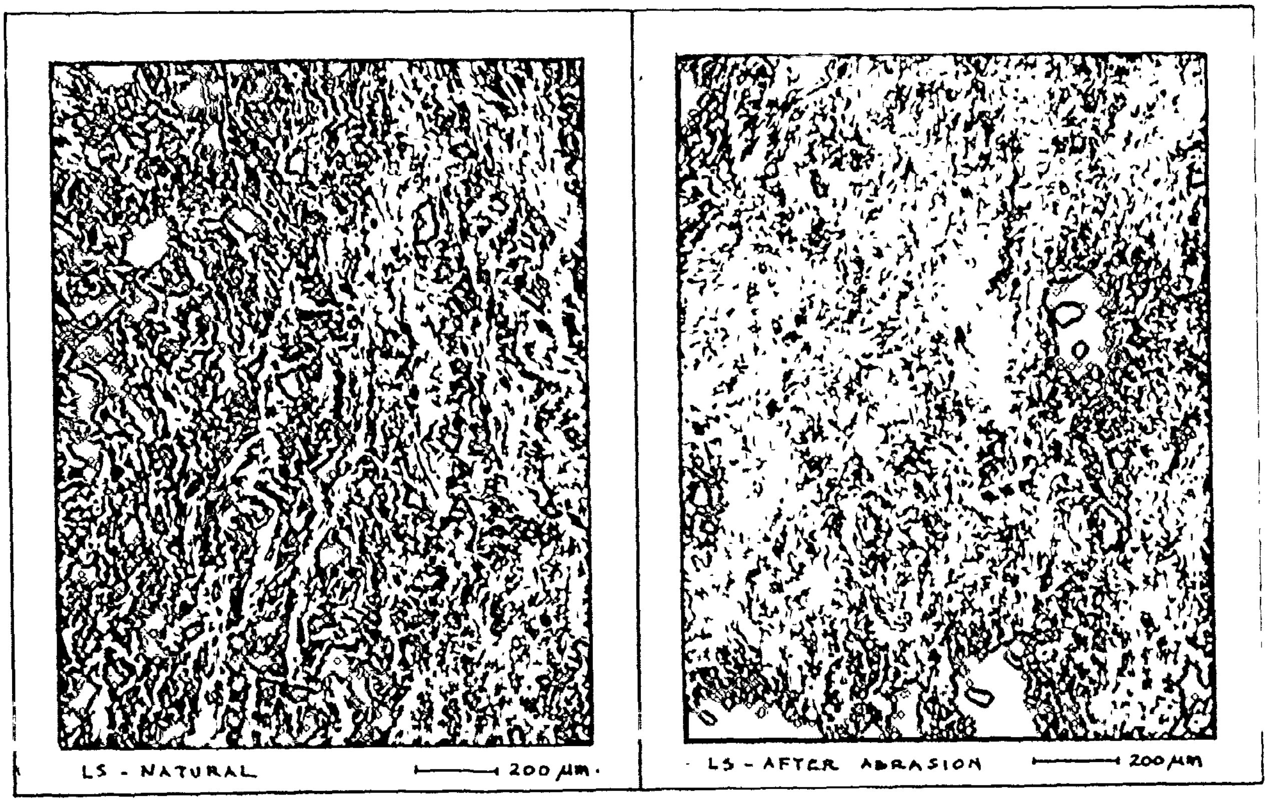


a. X1150 b. X1050

Figure 4. Traprock

c. X2300 d. X2300





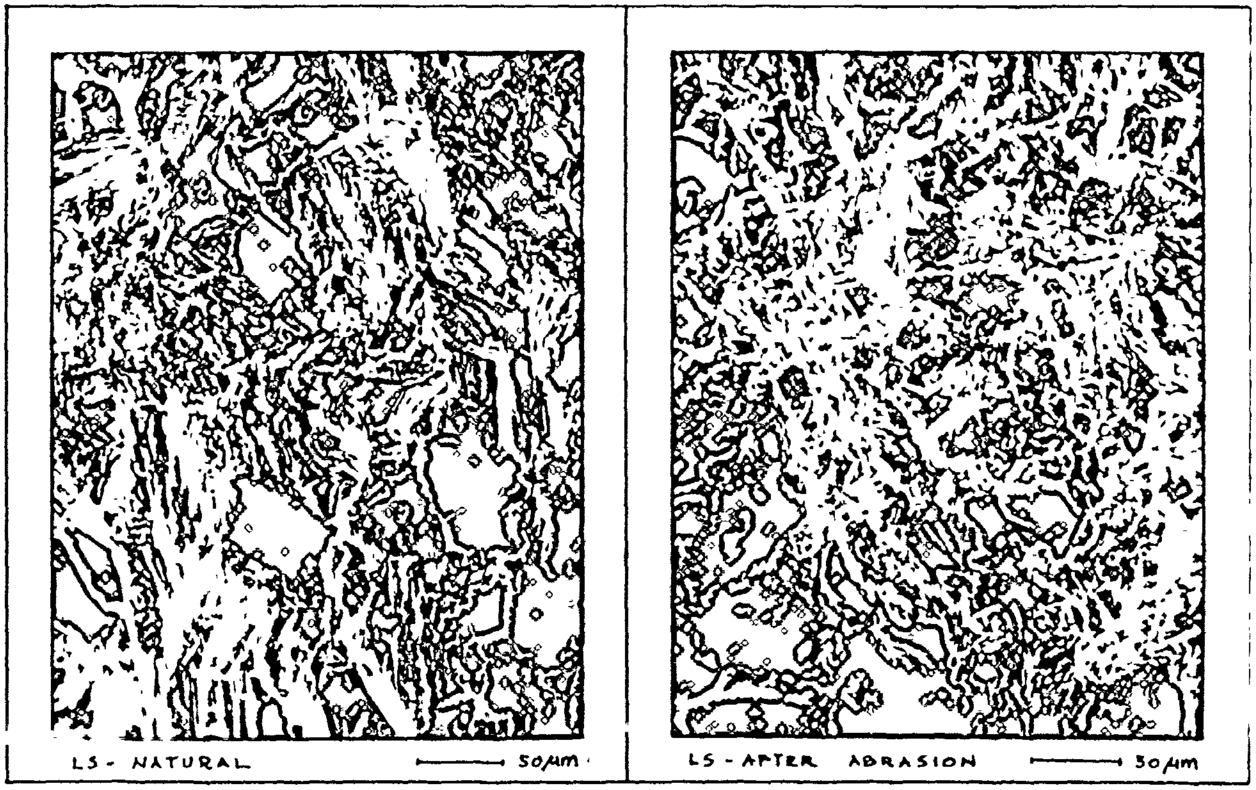
a. X56

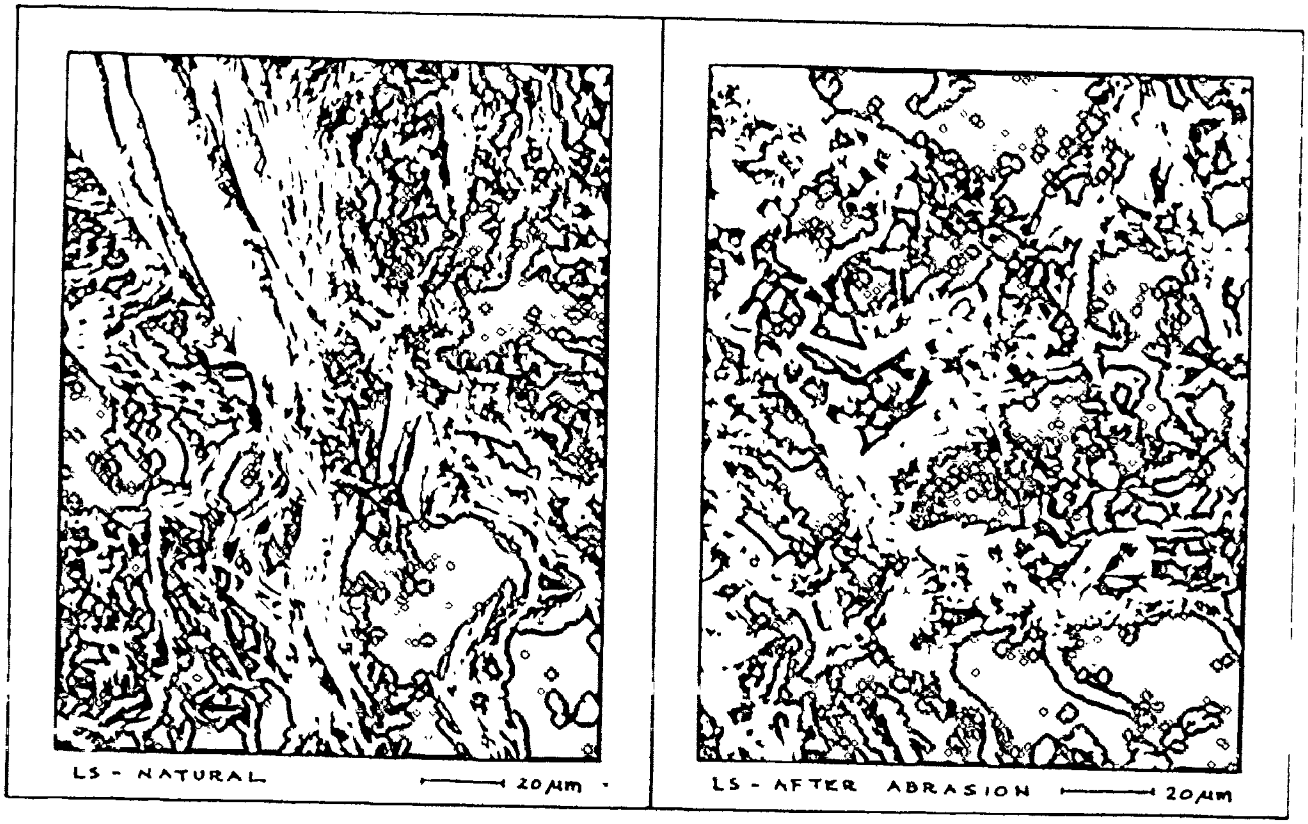
b. X60

Figure 5. Limestone

c. X240

d. X250





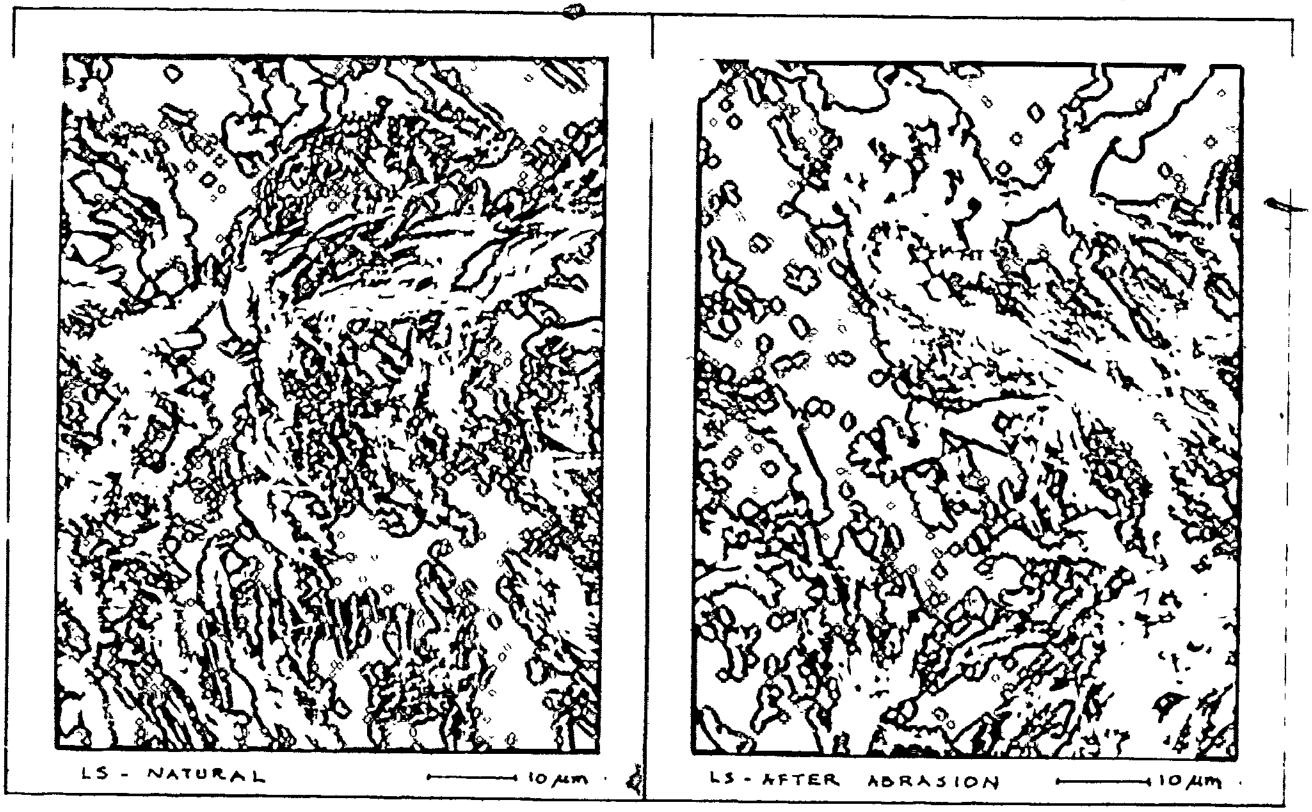
a. X550

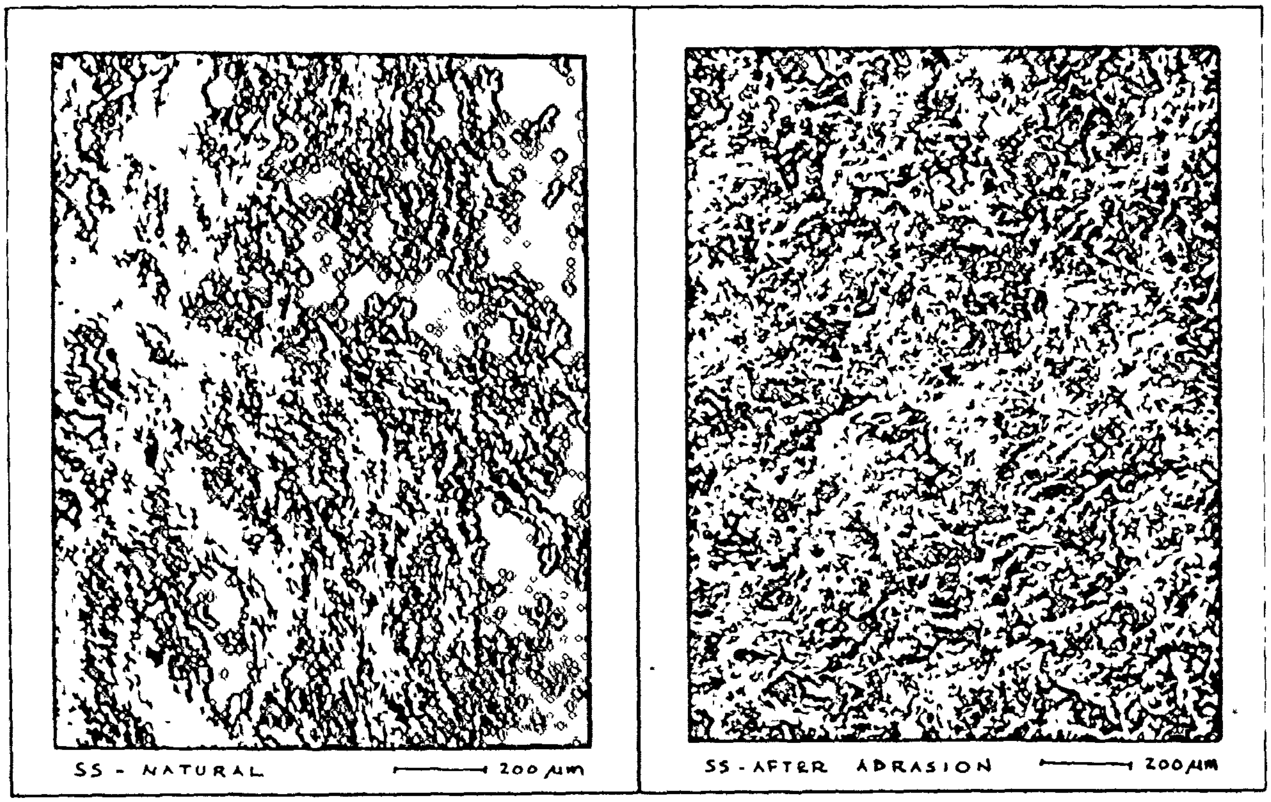
b. X625

Figure 6. Limestone

c. X1200

d. X1250





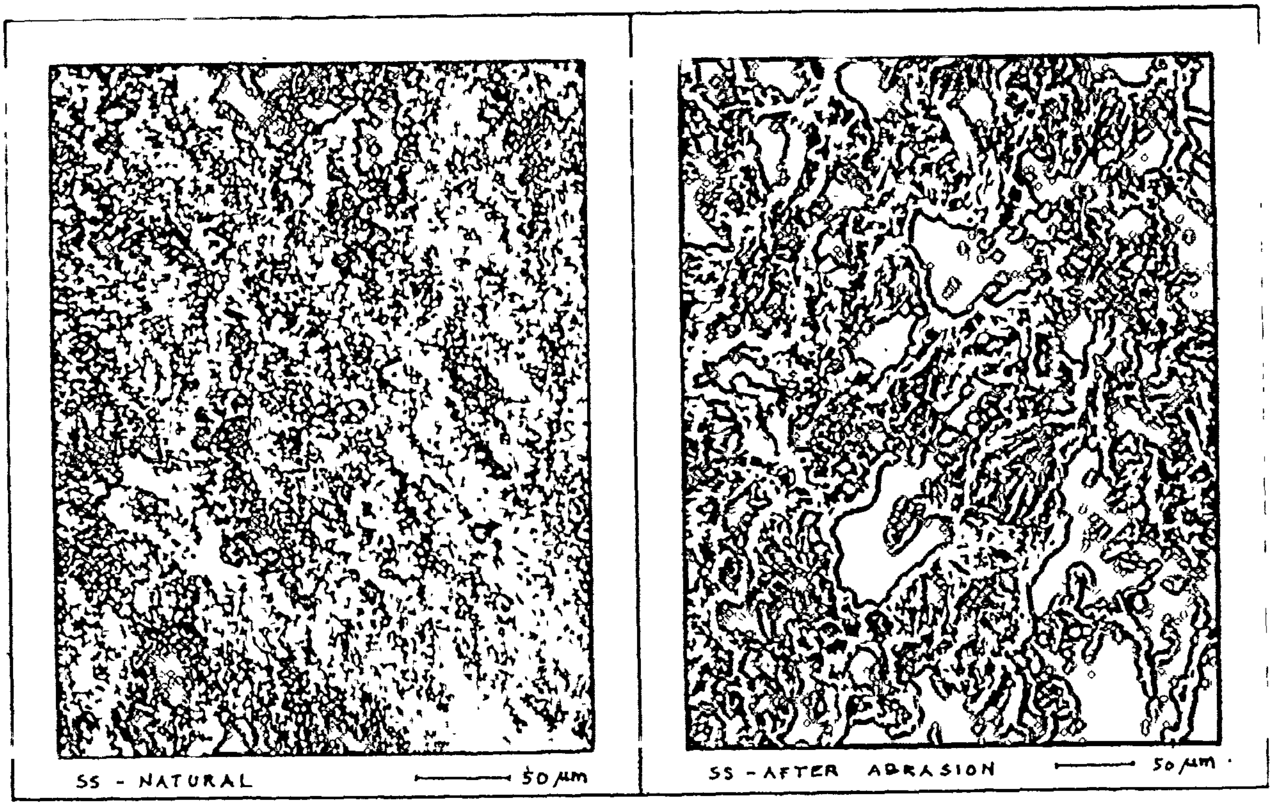
a. X64

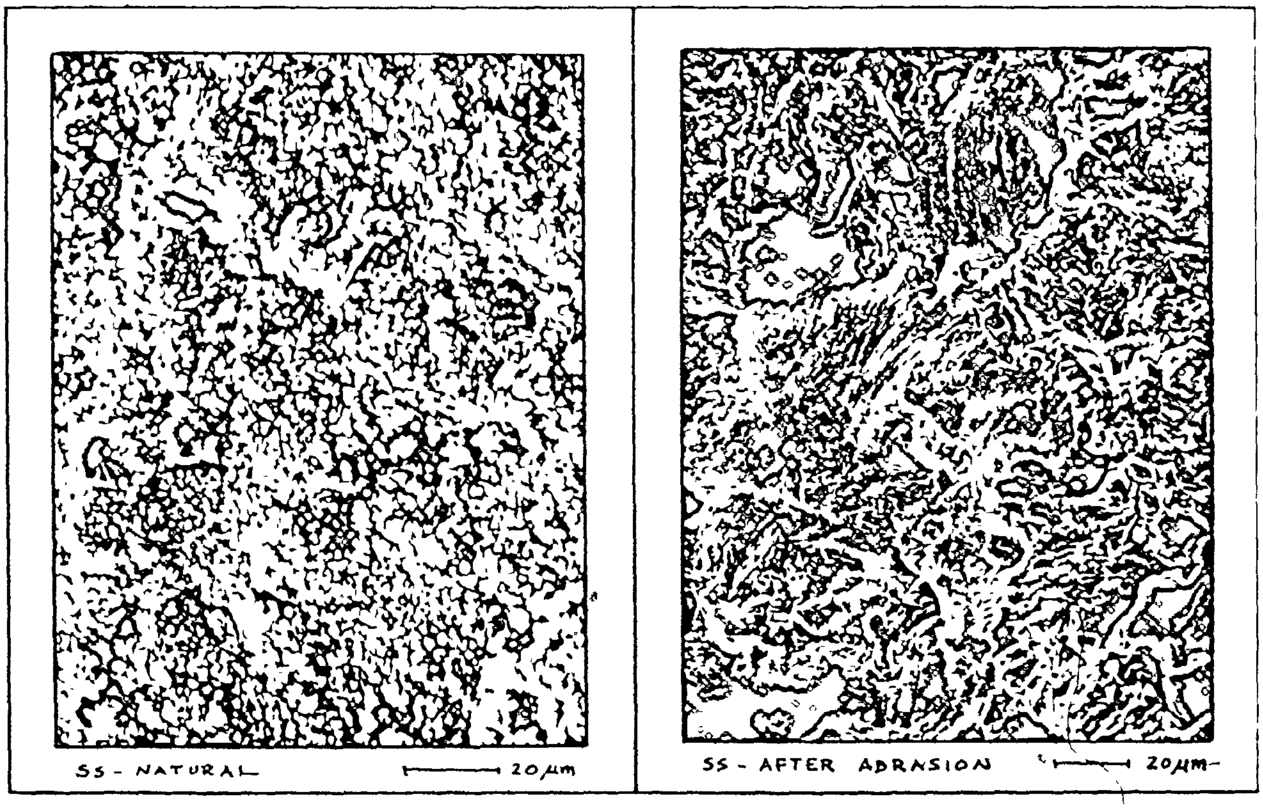
b. X63

Figure 7. Dofasco Steel Slag

c. X210

d. X1050





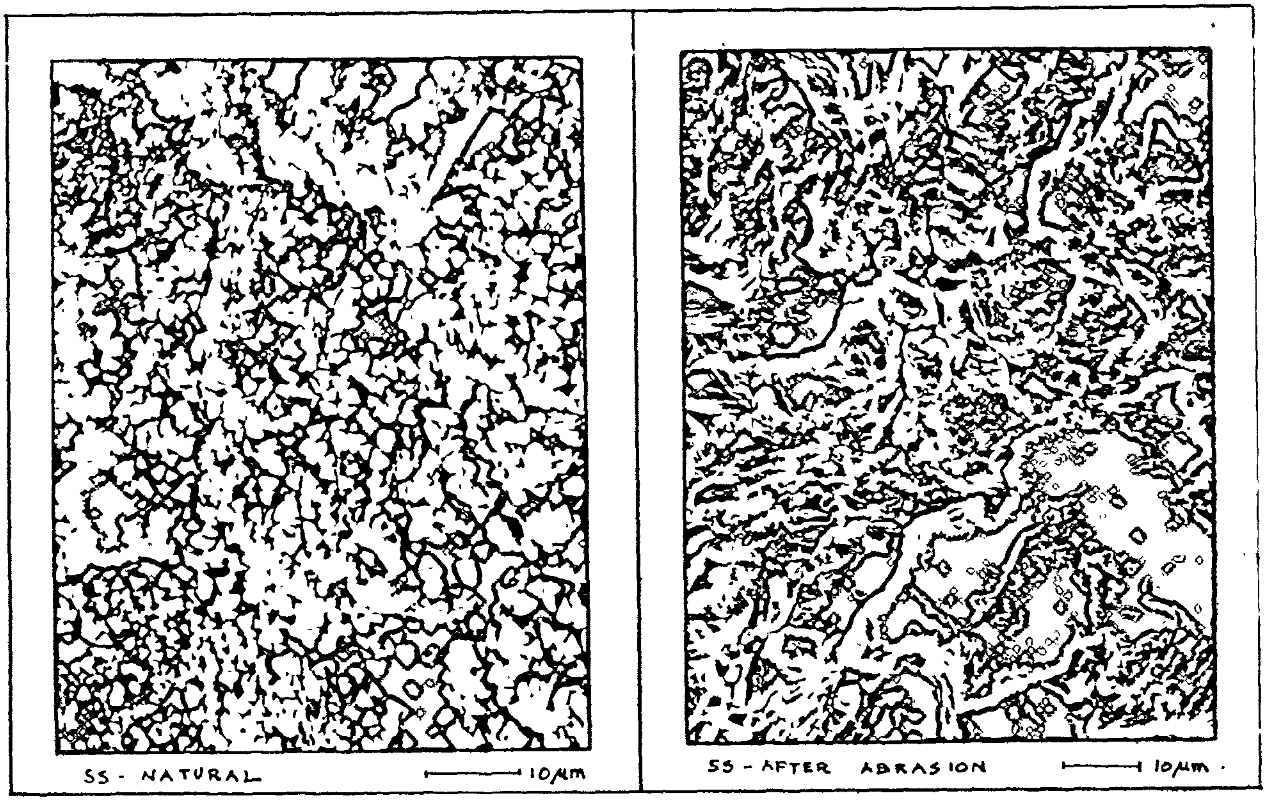
a. X650

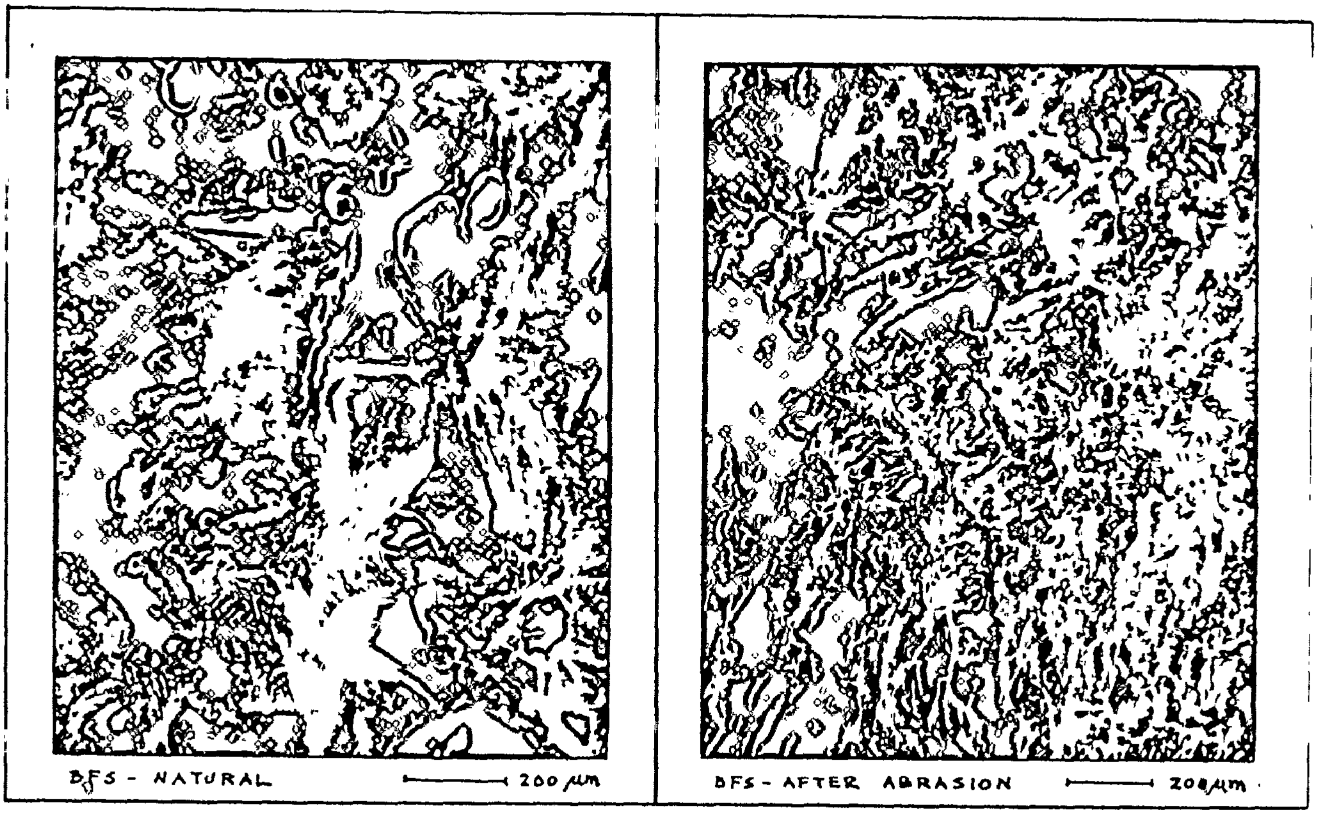
b. X520

Figure 8. Dofasco Steel Slag

c. X1300

d. X1050

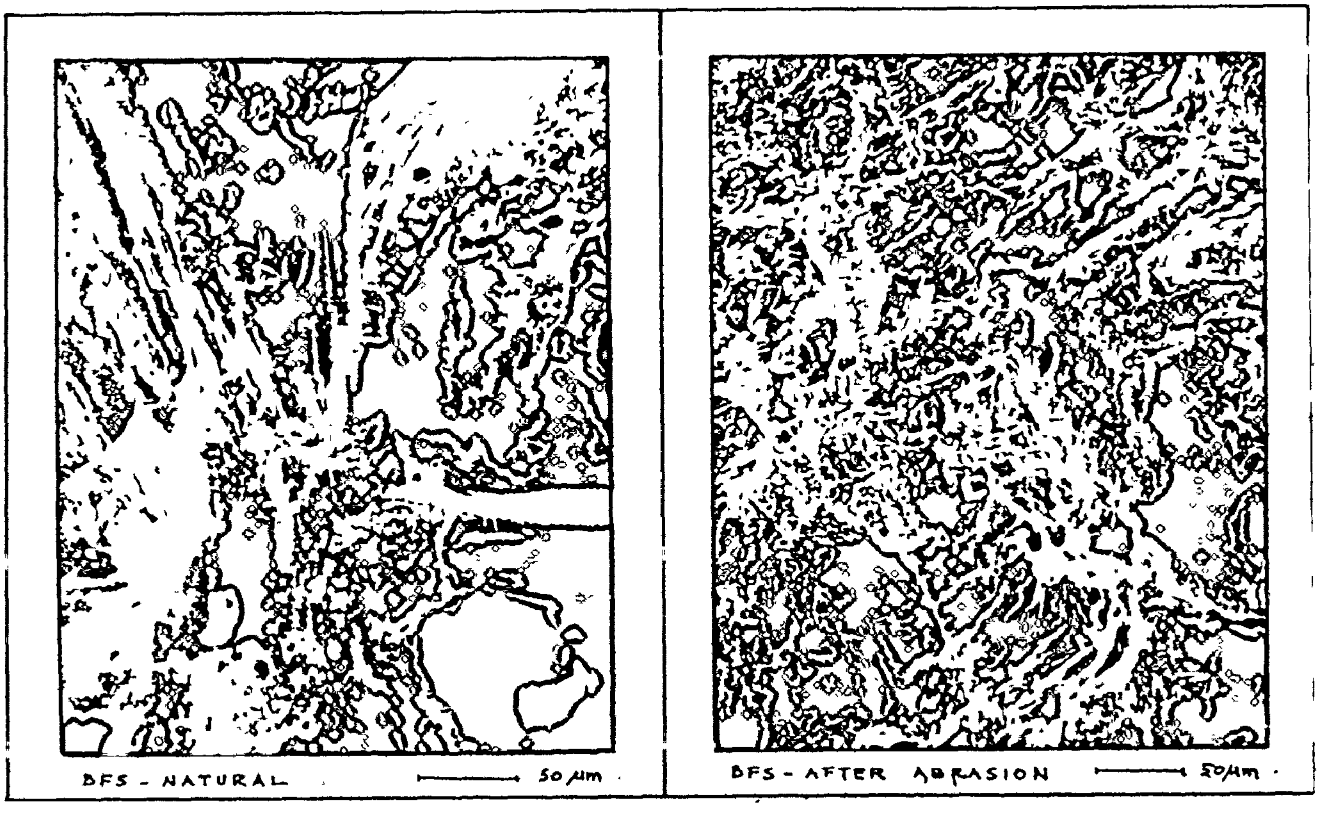


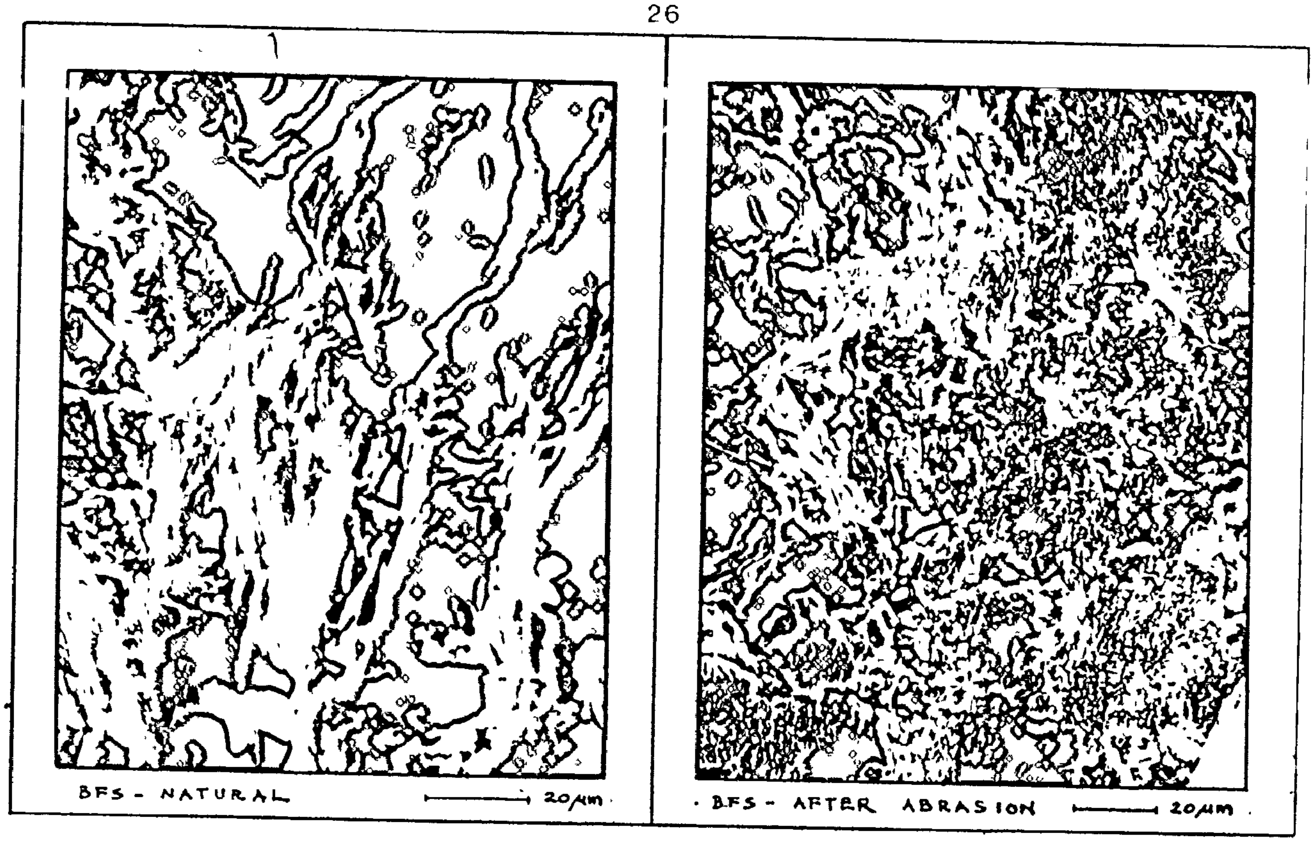


a. X66 b. X57

Figure 9. Blast Furnace Slag

c. X265 d. X230

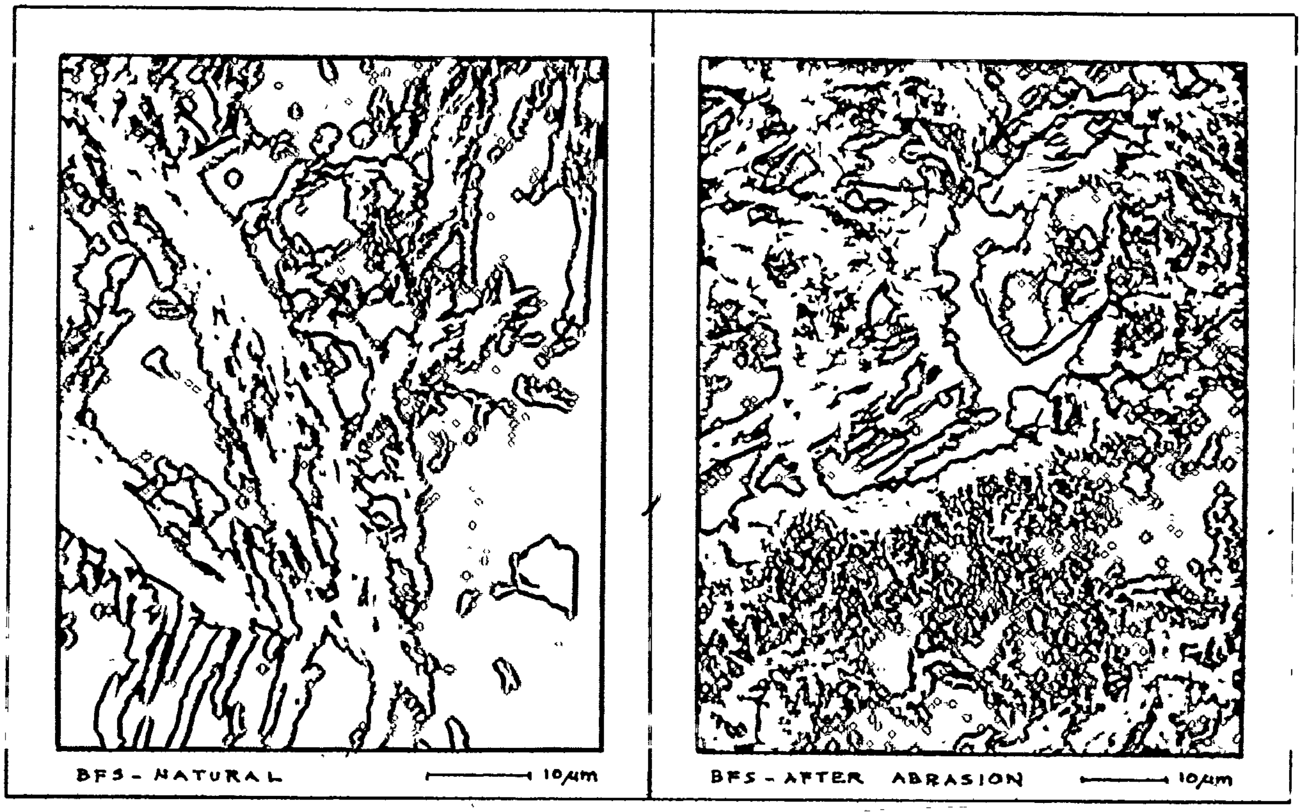




a. X690 b. X570

Figure 10. Blast Furnace Slag

c. X1380 d. X1130



2. Limestone

Photomicrographs for the limestone at about X50, X200, X500 and X1000 magnifications are given in Figures 5 and 6. Except that there is a general flattening of the surface macrotexture, the effect of abrasion was not clearly shown for the limestone. As shown in Figures 5d and 6b, the surface after abrasion is much flatter than in its natural condition, shown in Figures 5c and 6a. However, scouring and scratching cannot be seen in these photomicrographs. It is possible that because the limestone has a fairly high AAV (i.e., lower abrasion resistance), these features wear away. At about X1000 magnification, the natural and abraded surface textures are similar. Both of them are flat and they do not show good secondary microtexture.

3. Dofasco Steel Slag

Typical surface texture for the steel slag are shown in Figures 7 and 8 at about X50, X200, X500 and X1000 magnifications. The process of abrasion can be seen at all magnifications. The surface is flattened by the abrasion, and as shown in Figure 8b, scouring and scratching occur , which indicate that the surface is hard and tends to resist the abrasion. However, most of the "rich" texture which could be seen before abrasion in Figures 7c, 8a and 8c has gone. Therefore, for steel slag, abrasion appears to effect both the macrotexture and microtexture. At X1000 magnification, some secondary microtexture can still be seen.

4. Blast Furnace Slag

Typical surface textures for the blast furnace slag are shown in Figures 9 and 10 at about X50, X200, X500 and X1000 magnifications. Blast furnace slag generally has a high AAV, indicating a low resistance against abrasion. This is clearly shown in Figure 10d. Comparisons with the natural surface condition of the blast furnace slag show that abrasion has flattened the surface. However, since blast furnace slag has numerous pores and "depressed" areas, some texture can still be seen after the abrasion.

3.4.2 SUMMARY

The observations on the effect of accelerated, simulated abrasion on the surface texture of the aggregates can be summarized as follows:

1. Visual observations using the SEM are helpful in examining the process of abrasion on aggregates. Generally, abrasion flattens the major surface texture of the aggregate. Therefore, it clearly changes the macrotexture of the surface to a degree depending on the hardness of the aggregate (i.e., resistance to abrasion or AAV).
2. The process of abrasion also effects the primary microtexture of the aggregate . However, this effect varies a great deal among the aggregates, which may be caused by the physical and chemical characteristics of the aggregate and its natural surface texture.
3. Secondary microtexture generally remains unaltered, as clearly shown at high magnification photomicrographs (i.e., at about X2000).
4. Traprock and steel slag have a good resistance against abrasion, as indicated by their low AAV values (9, 10). The photomicrographs show scouring and scratching on the surface of both traprock and steel slag, which are an indication of the resistance to abrasion.
5. Limestone, which has an intermediate AAV of 8.3 (10) does not show any scouring and scratching on its surface. However, due to its physical characteristics, "chipping" occurs during abrasion, so that the final texture after abrasion tends to be rather rough (i.e., abrasion sand can "scratch" the soft surface).

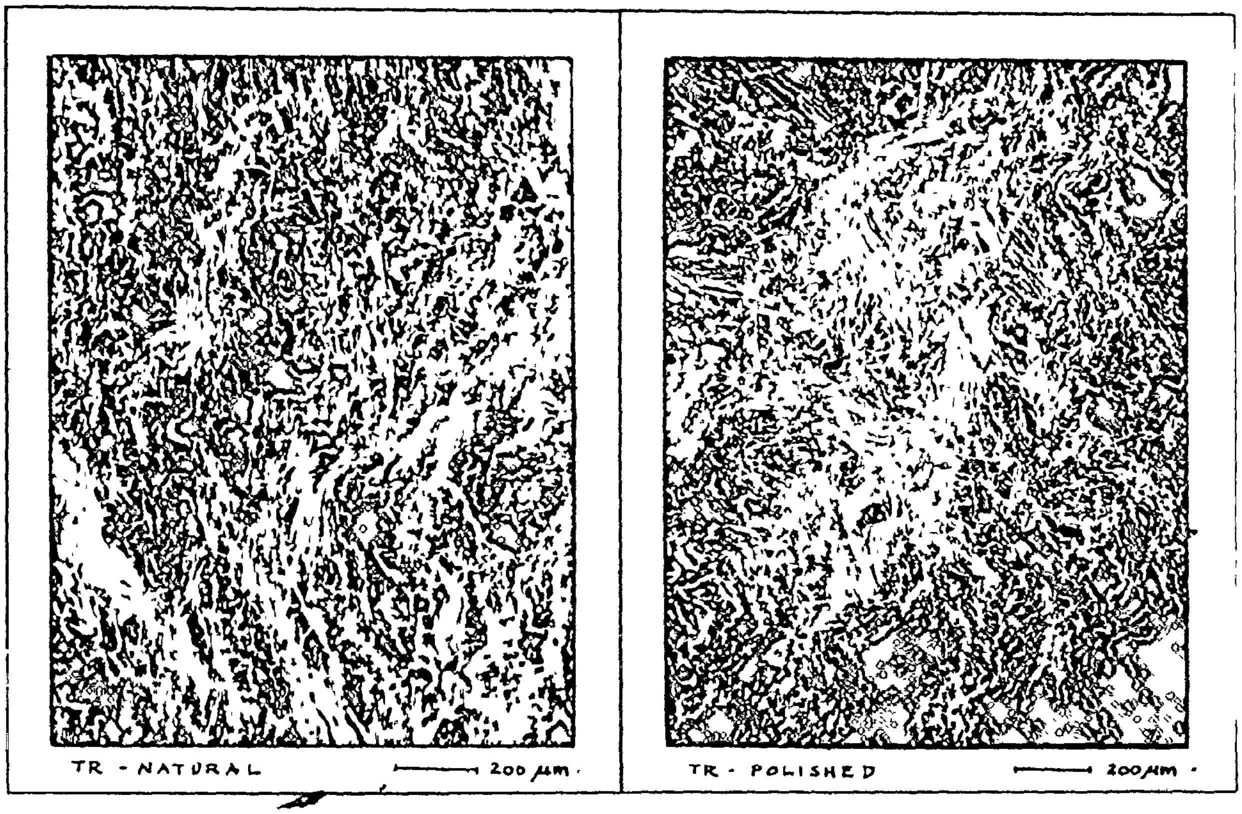
6. For aggregates which have high AAV values, such as blast furnace slag (9, 10), the process of abrasion flattens the surface very easily. After abrasion the surface is flat and smooth. However, abrasion cannot occur in any depressed areas, so that any cracks and pores still provide fairly good microtexture.

3.5 EFFECTS OF POLISHING ON THE SURFACE TEXTURE OF THE AGGREGATES

3.5.1 EVALUATION RESULTS

Unlike the process of abrasion, the polishing of aggregate surfaces is carried out by much finer particles. In the polishing process using the British Polishing Machine (BS 812, Reference 6), the aggregate samples are first polished by corn emery. Then, they are further polished by emery flour to the end condition anticipated under actual traffic conditions in the field.

The typical photomicrographs obtained from the SEM observations of polished aggregates are given in Figures 11 to 18. Photomicrographs were taken at about X50, X500, X1000 and X2000 magnifications. Photomicrographs were taken on both unpolished and polished aggregate surfaces, so that comparisons could be made.



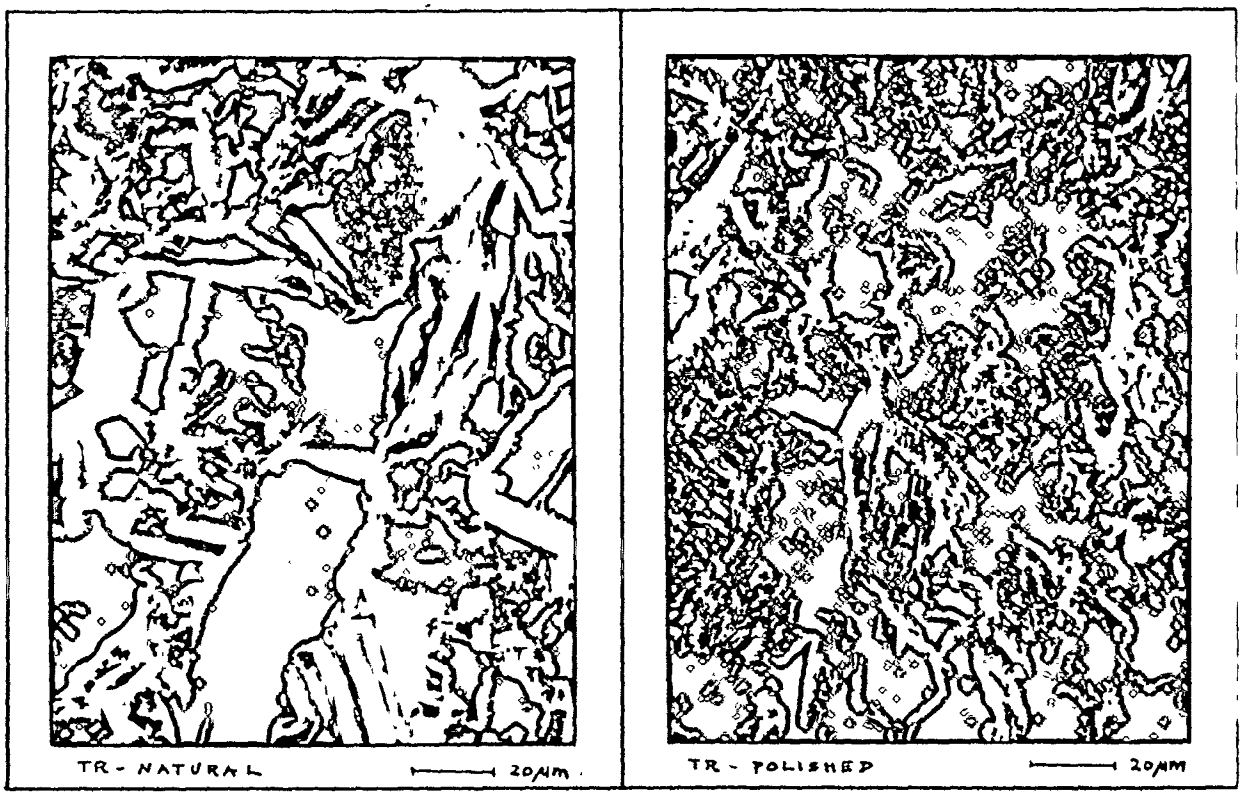
a. X58

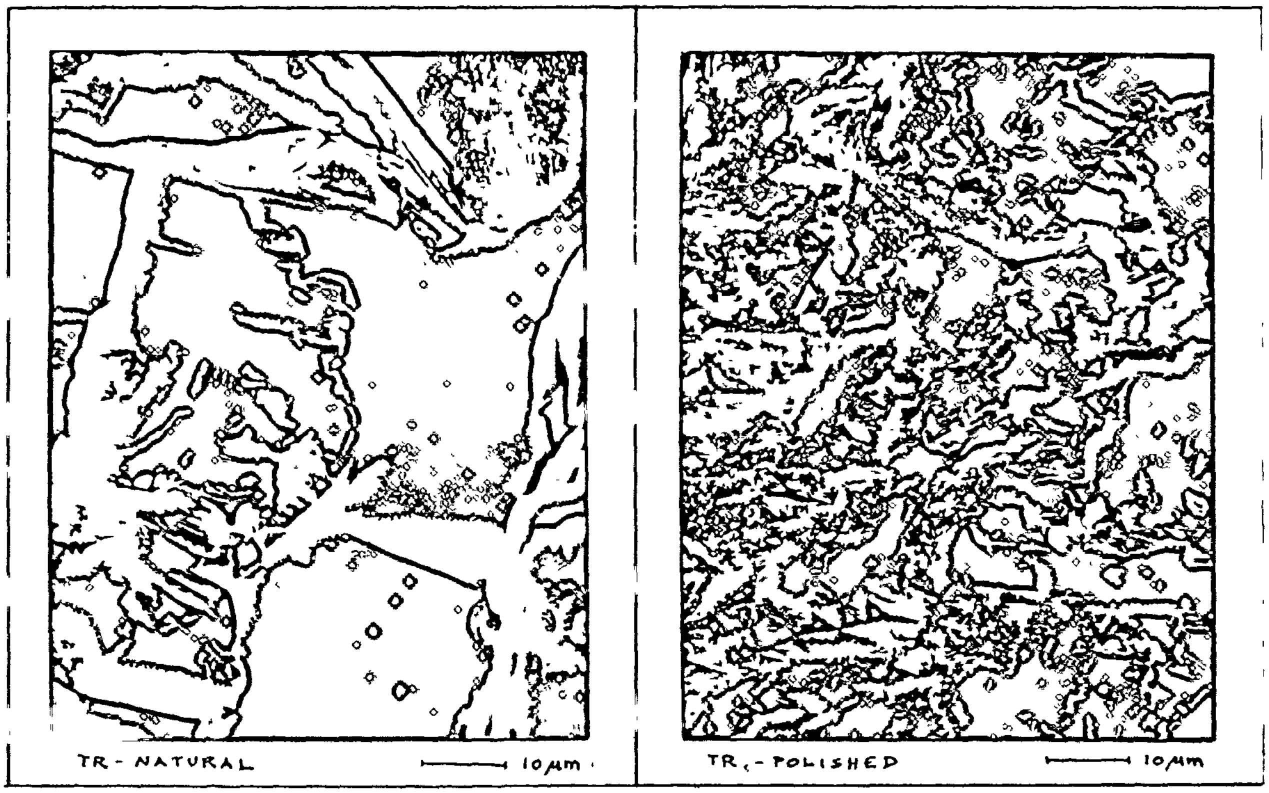
b. X53

Figure 11. Traprock

c. X575

d. X590





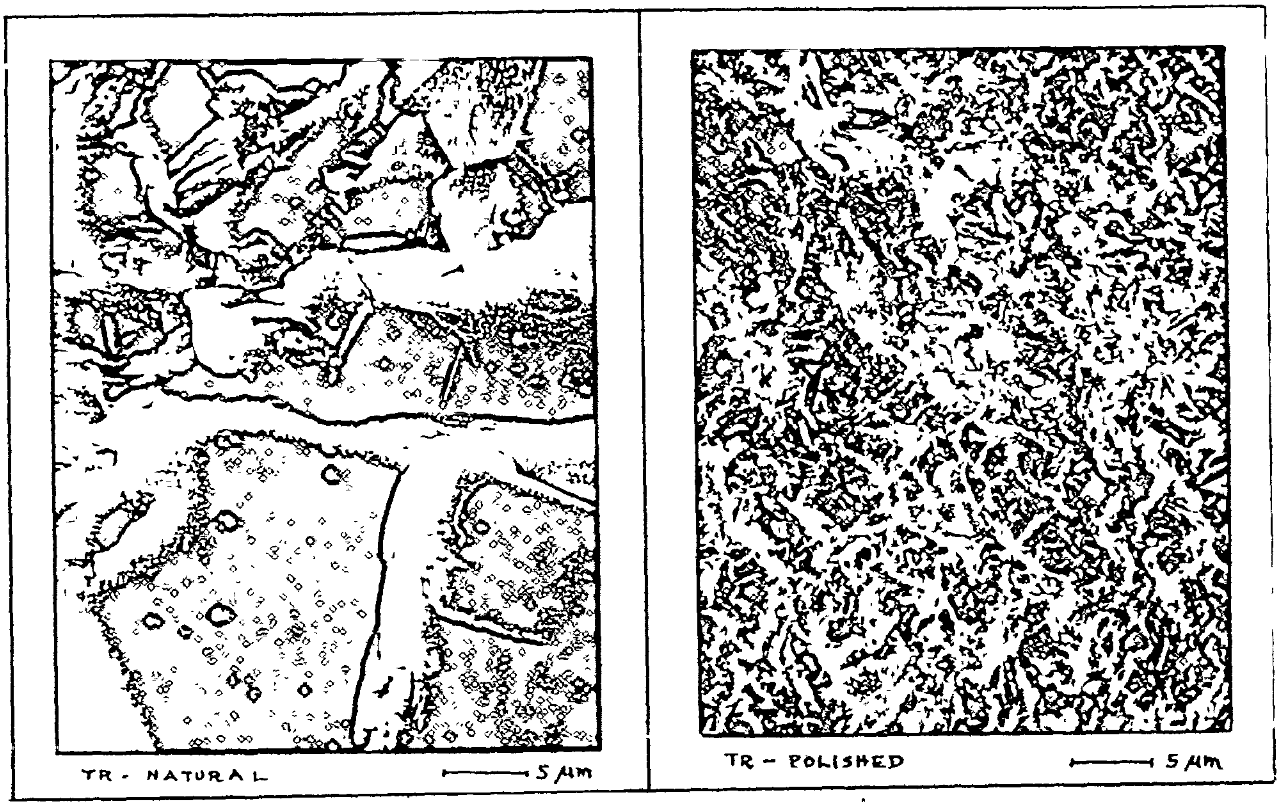
a. X1150

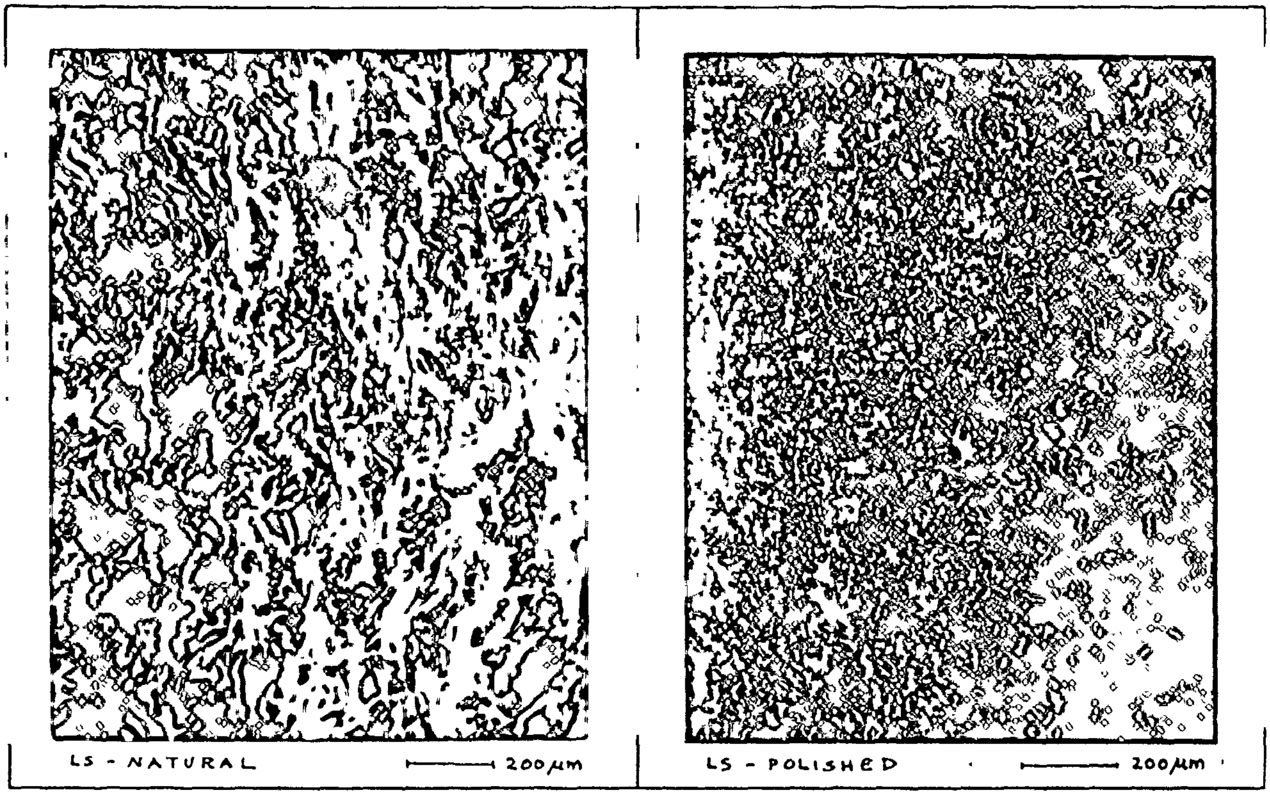
b. X1160

Figure 12. Traprock

c. X2300

d. X2300





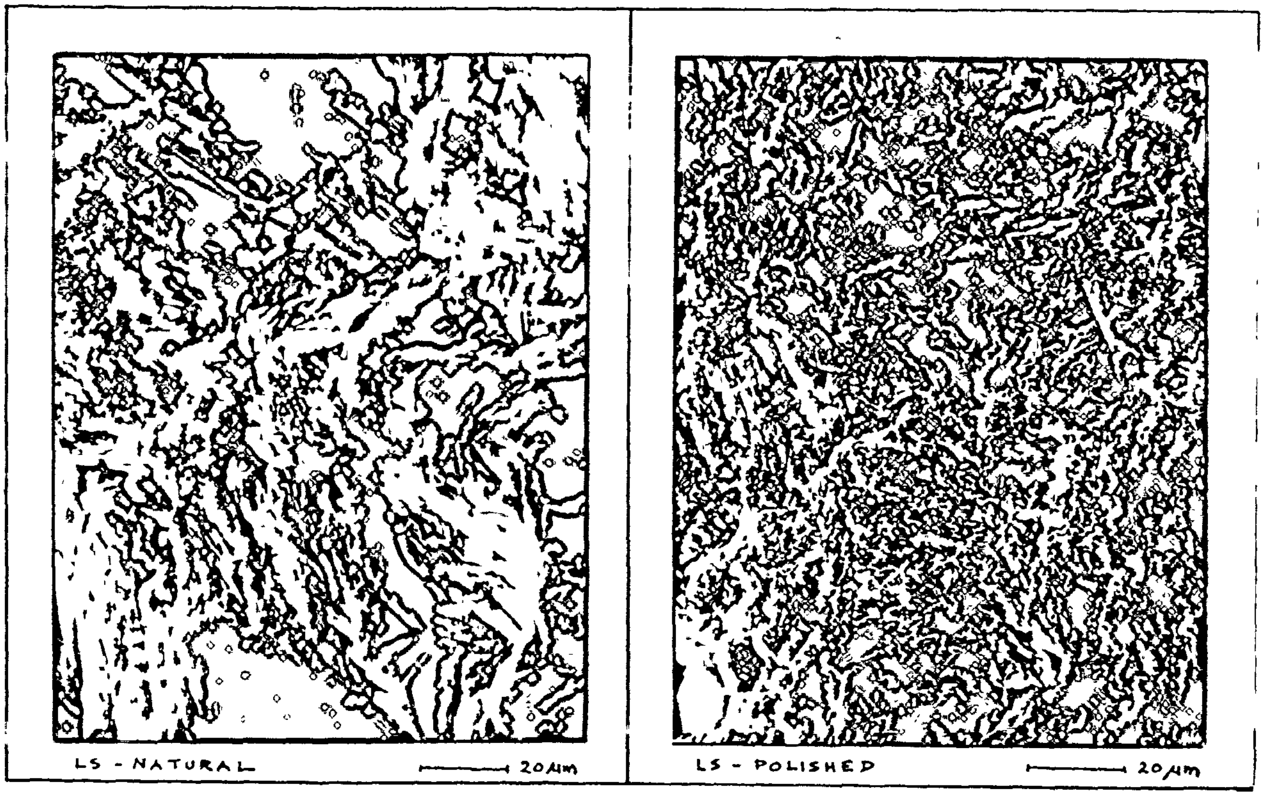
a. X60

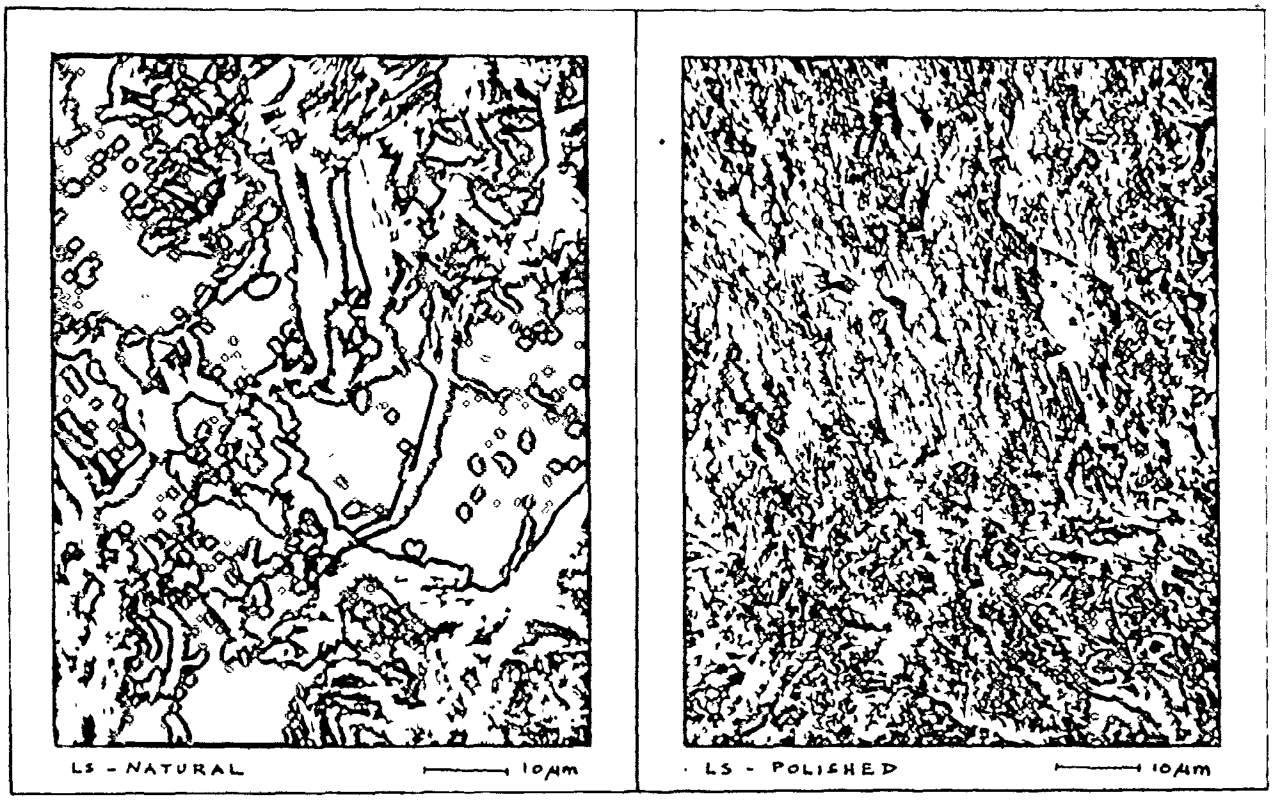
b. X67

Figure 13. Limestone

c. X600

d. X670

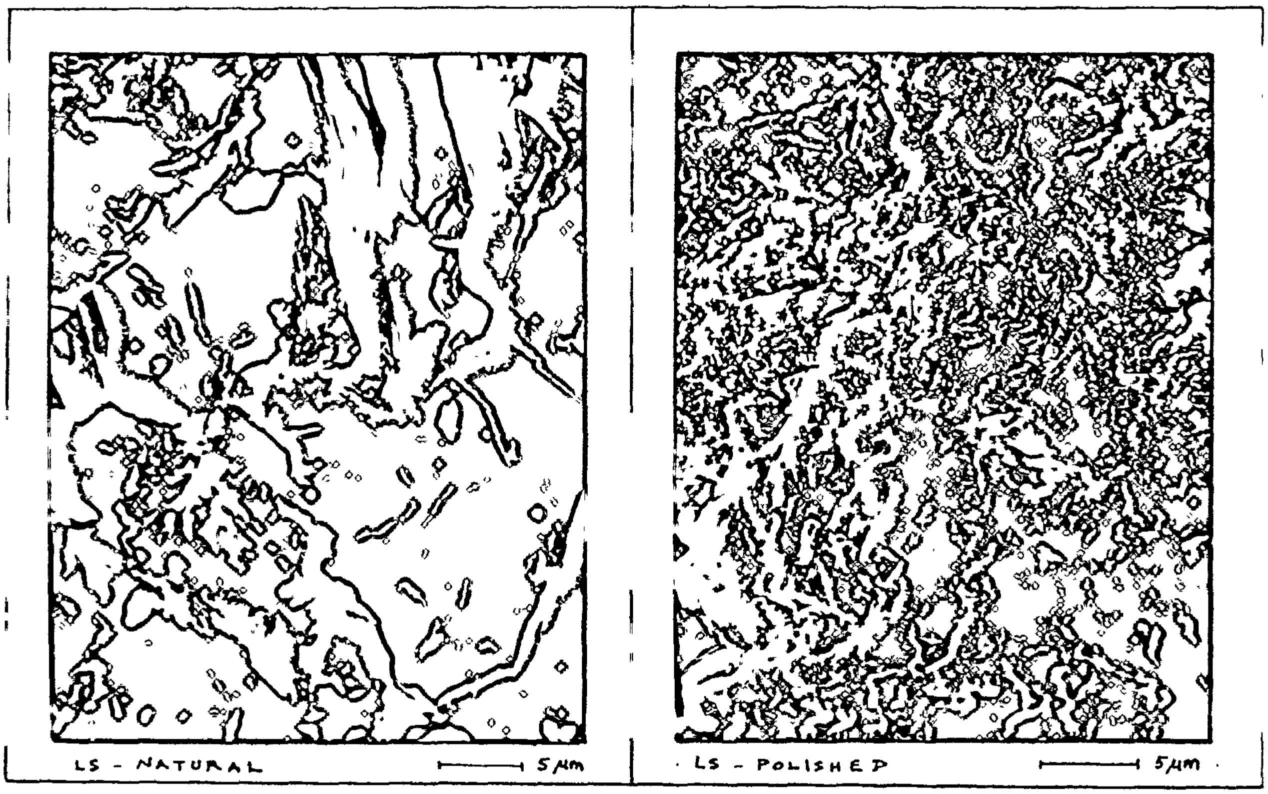


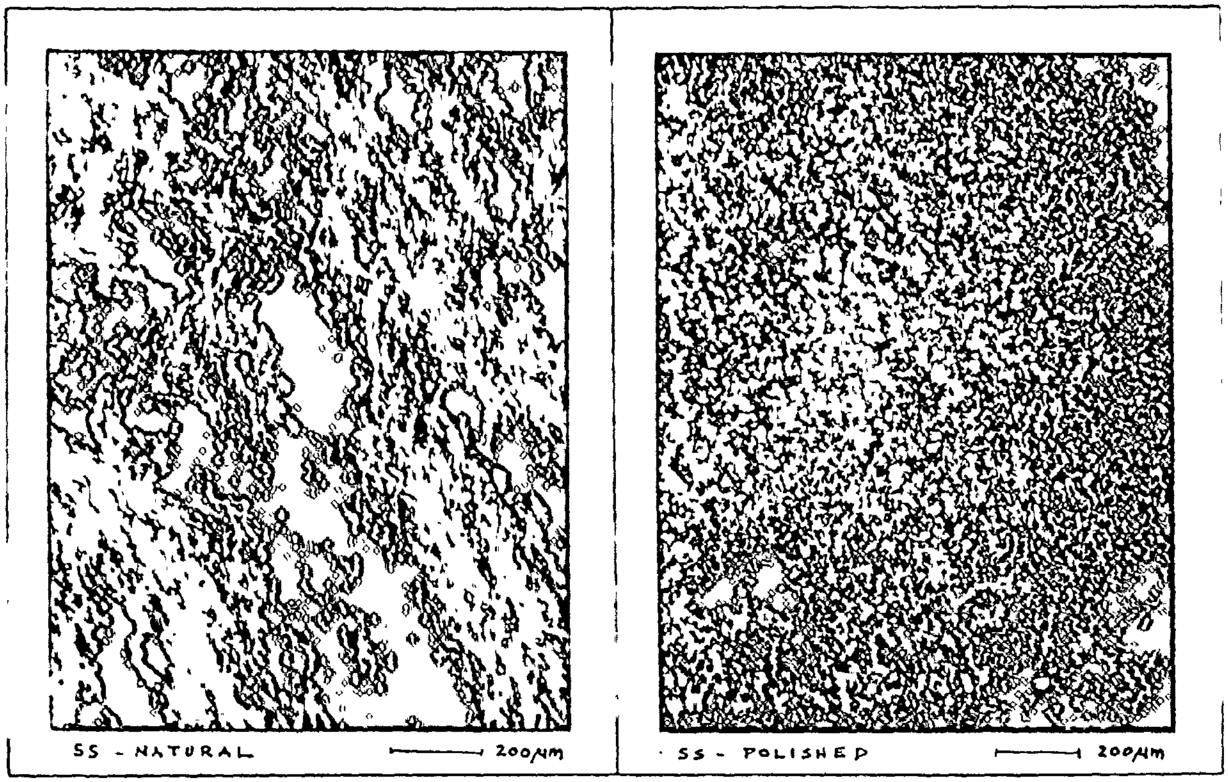


a. X1130 b. X1160

Figure 14. Limestone

c. X2250 d. X2700





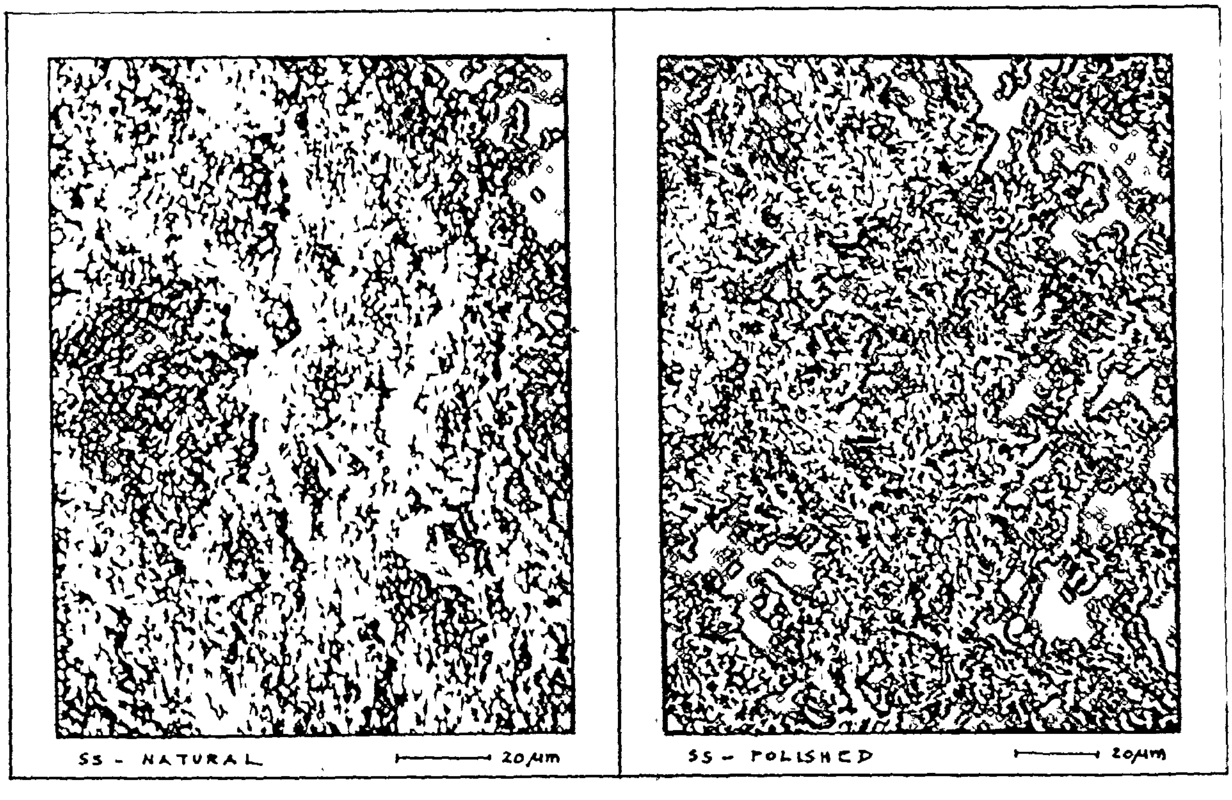
a. X66

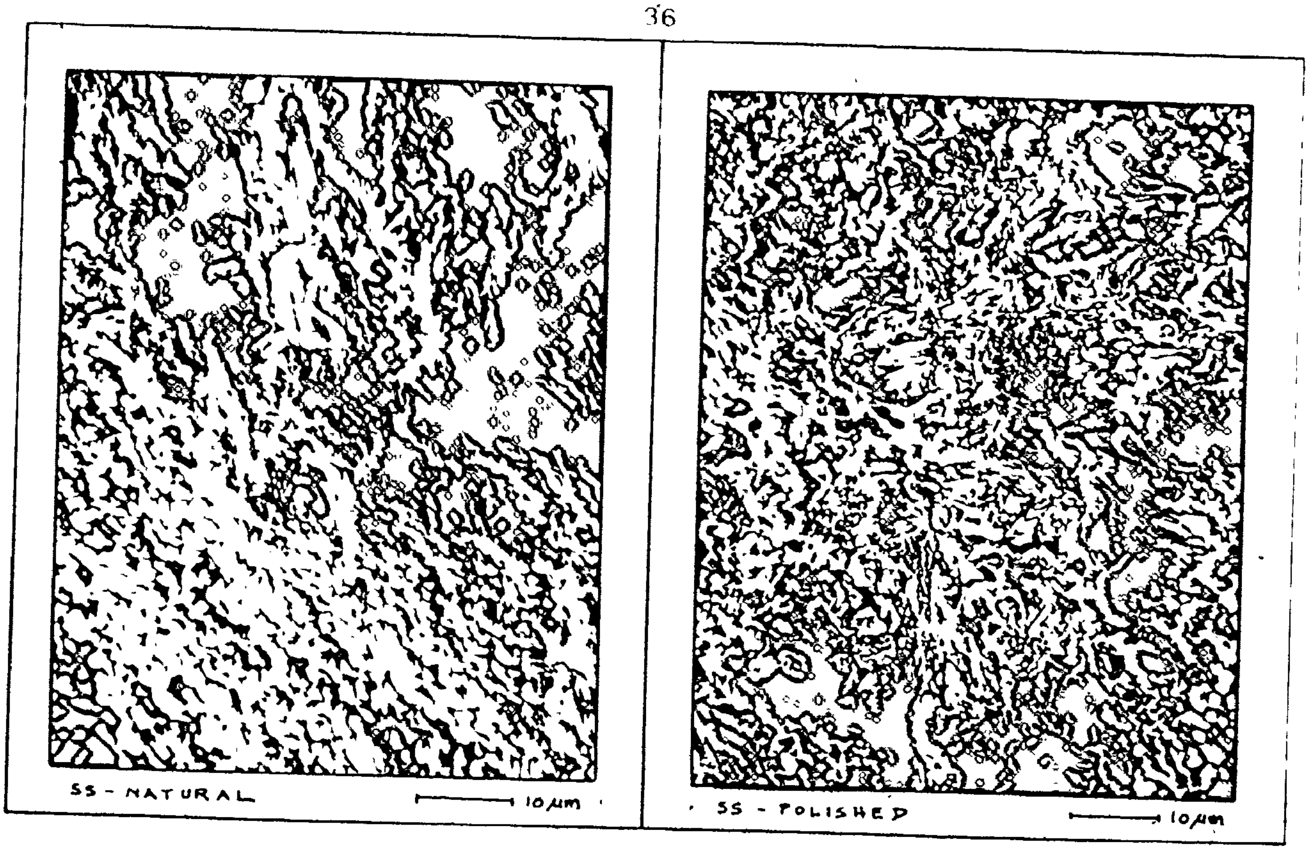
b. X59

Figure 15. Dofasco Steel Slag

c. X660

d. X590





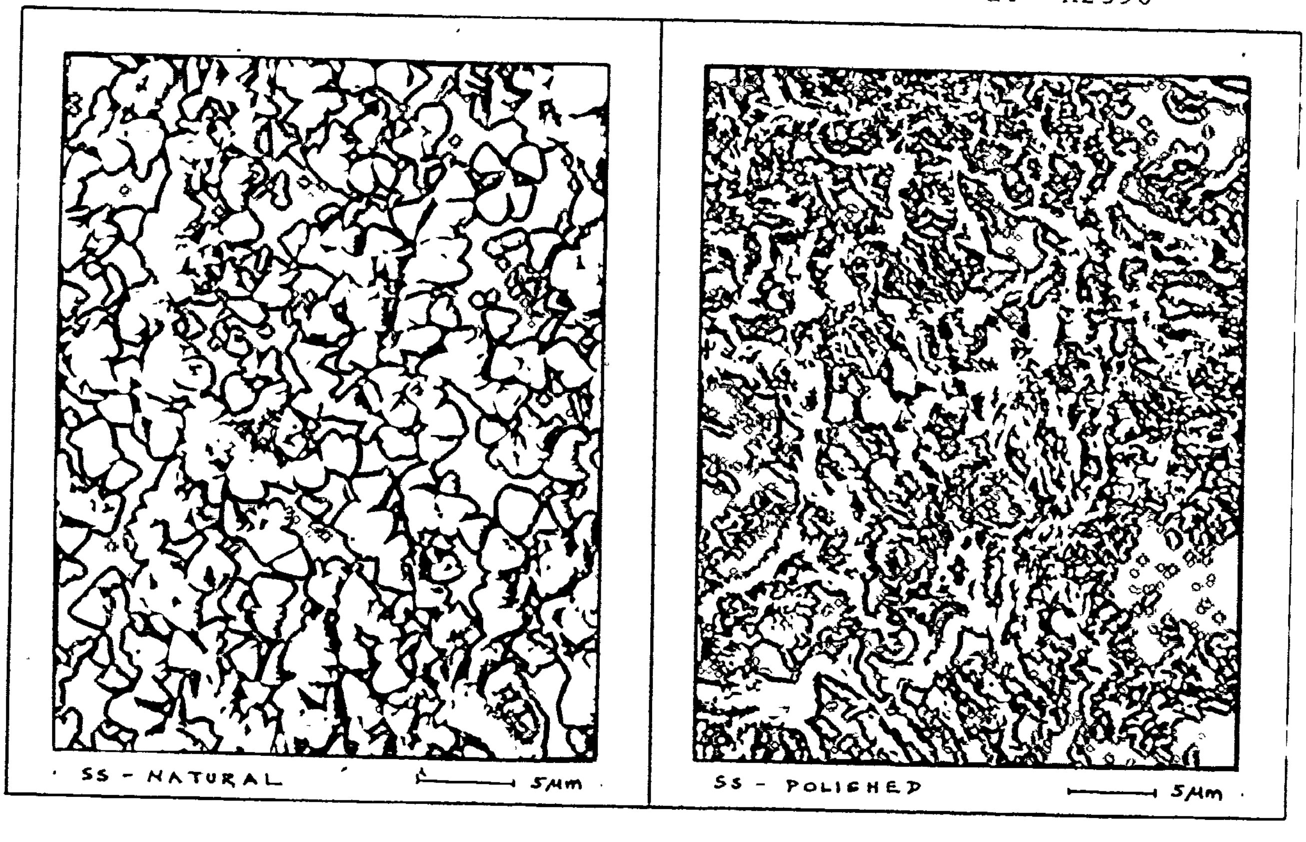
a. X1280

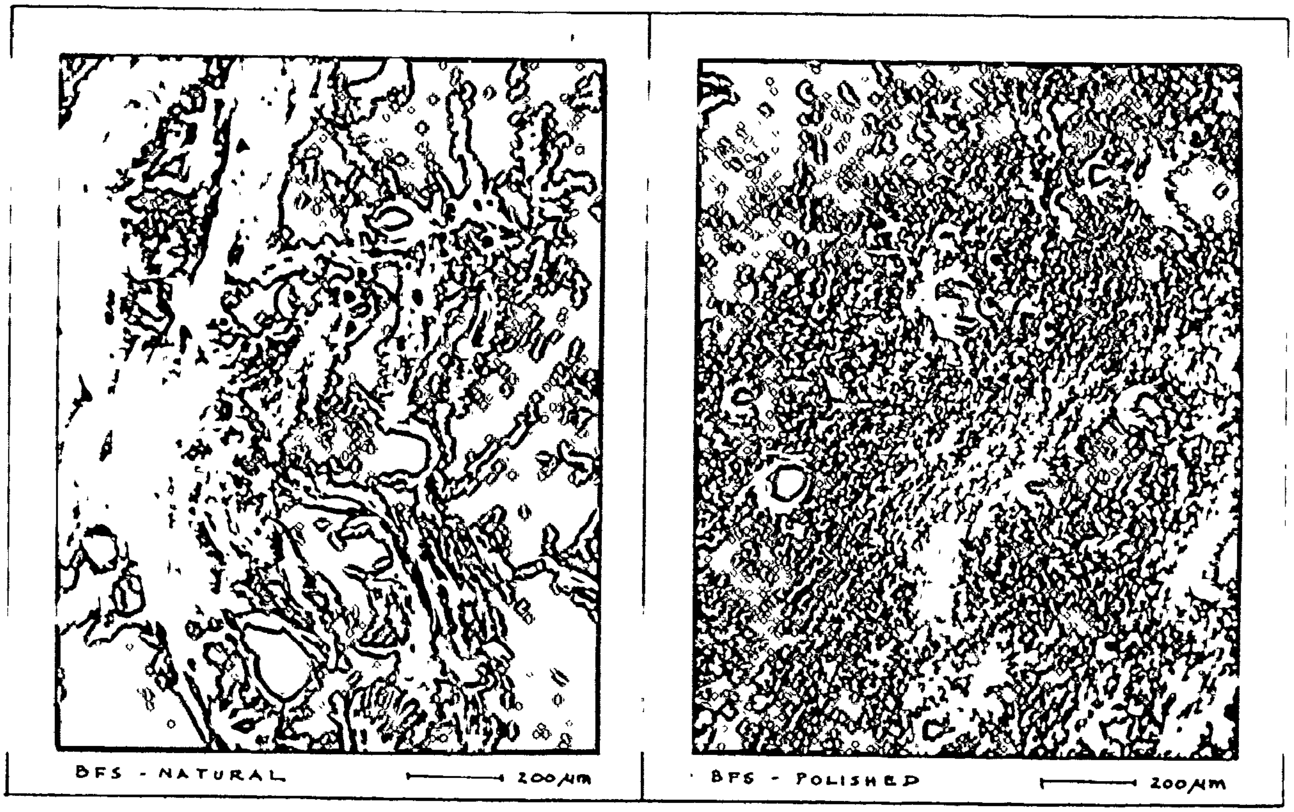
b. X1200

Figure 16. Dofasco Steel Slag

c. X2600

d. X2390





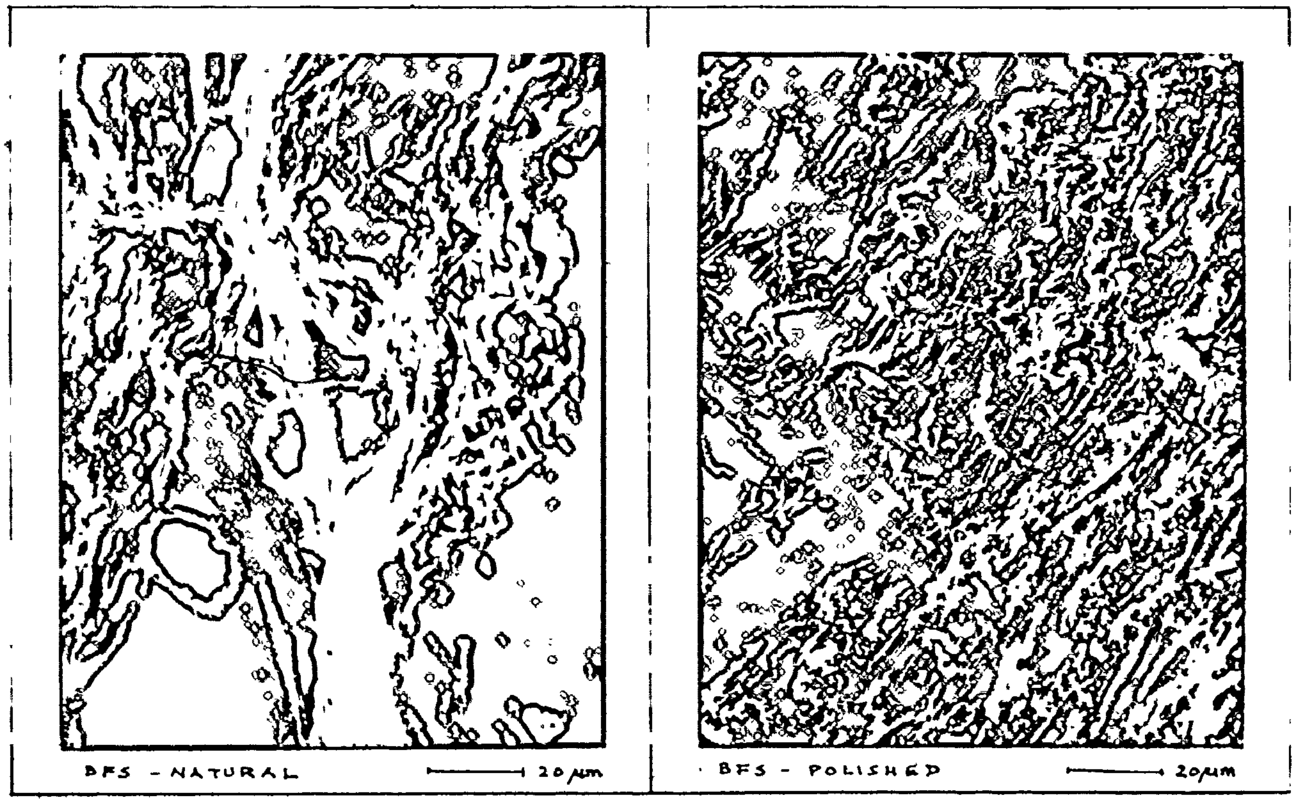
a. X64

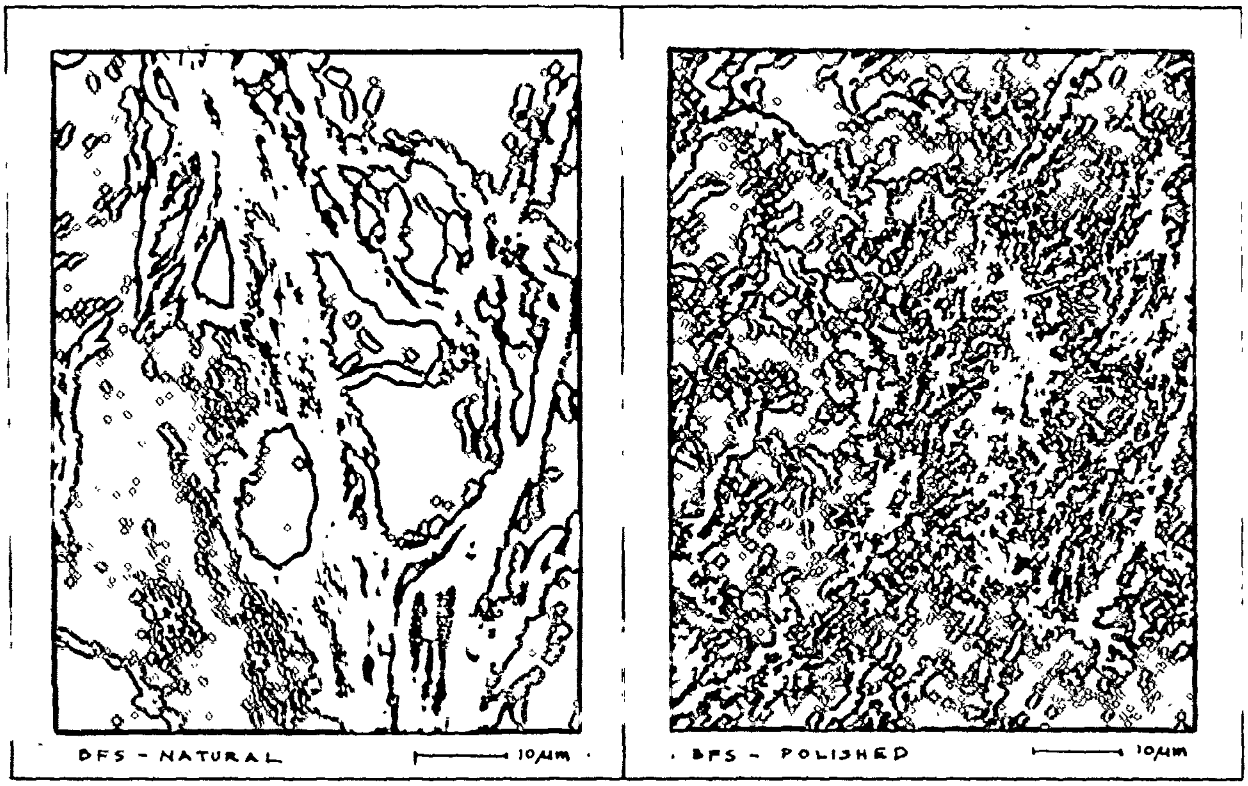
b. X64

Figure 17. Blast Furnace Slag

c. X640

d. X640





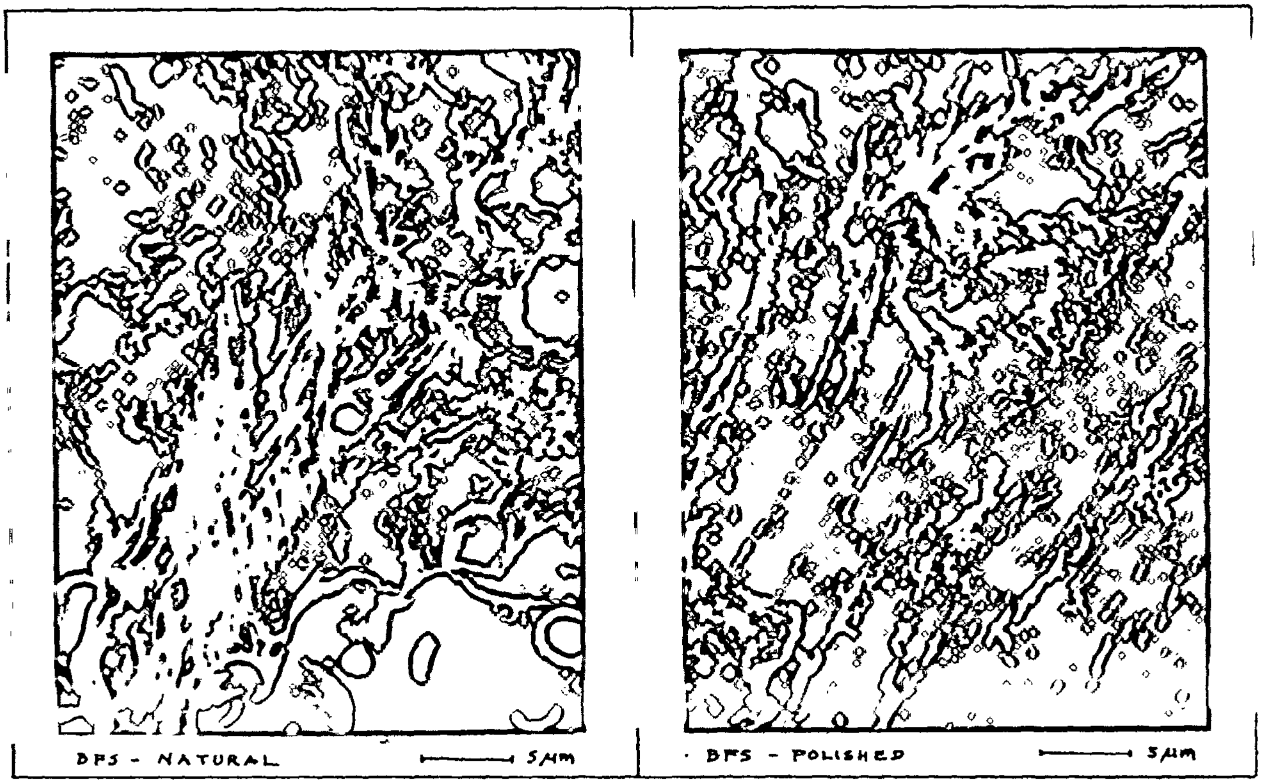
a. X1280

b. X1240

Figure 18. Blast Furnace Slag

c. X2550

d. X2450



The visual observations from these photomicrographs can be described as follows:

1. Traprock

The photomicrographs for the traprock are shown in Figures 11 and 12. There is a clear distinction between the unpolished and polished traprock which can be seen at all magnifications. The polished samples show a smooth surface texture at all magnifications, and all of the rough edges have been polished. However, at low magnification, as shown on Figure 11b, the surface texture can still be seen. This indicates that polishing of traprock does not flatten the macrotexture and the whole surface area; but it only polishes the microtexture.

2. Limestone

The photomicrographs for the limestone are shown in Figures 13 and 14. In contrast to traprock, Figures 13a and 13b show that the limestone surface has been polished very easily. Depressed areas shown in Figure 13a are removed during the polishing. Furthermore, photomicrographs at other magnifications also show that polishing has changed both the primary and secondary microtexture of the limestone. The primary microtexture which is shown in its natural condition in Figure 13c and 14a has been removed during the polishing process. The secondary microtexture, which is rather flat in its natural condition, becomes even flatter during polishing.

3. Dofasco Steel Slag

Figures 15 and 16 show typical surface textures for Dofasco steel slag, both in the polished condition and unpolished condition. As shown in these photomicrographs, steel slag in its natural condition has a very "rich" texture, especially secondary microtexture as shown in Figure 16c. The effects of polishing can be seen in the polished condition photomicrographs at all magnifications. Polishing tends to smooth the surface texture of steel slag. However, as shown in Figure 16d, secondary microtexture is still evident. Similarly, the primary microtexture shown in both Figures 14d and 15b was not completely polished.

4. Blast Furnace Slag

Visual observations of blast furnace slag show that it can contain several different types of particles ranging from the usual vesicular material to impurities from the process such as iron, dark and glassy type aggregates and many others. However, most of the blast furnace slag was in the typical closed, vesicular form shown in Figures 17 and 18. As shown in its natural condition, blast furnace slag has some texture with many pores and micropores. As shown in the photomicrographs, the surface texture became very smooth after polishing. The photomicrographs shown in Figures 17 and 18 are typical of blast furnace slag. In contrast, observations on other types of particle in blast furnace slag might have shown different characteristics of polishing. Therefore, the effect of polishing on blast furnace slag depends on the type of individual material chosen for the observation.

3.5.2 SUMMARY

The visual observations on the effect of polishing can be summarized as follows:

1. Comparing Figures 3 to 10 with Figures 11 to 18, it was found that abrasion and polishing effect the surface texture of aggregates differently. Generally, the abrasion process effects the whole surface area, i.e., the macrotexture; whereas polishing effects the aggregate microtexture more. However, depending to the type of aggregates, both abrasion and polishing may effect both microtexture and macrotexture.

2. Generally, the final "finish" of the surface texture after polishing can be seen on all of the aggregates. Unlike abrasion, the polishing process smooths the rough texture, such as grain textures, edges, which are seen at high magnifications (i.e., secondary microtexture).
3. Traprock, which has an intermediate PSV (9), had a good primary microtexture, although all the edges had been polished. Secondary microtexture did not show up for the traprock.
4. The polishing of limestone resulted in a very smooth surface texture. After polishing, the primary microtexture was not as high as the traprock's, since it had been flattened and polished significantly. There was no secondary microtexture shown on the polished limestone surface.
5. For steel slag, the secondary microtexture, which can be seen at X2000 magnification shows some polishing. However, the texture is not completely polished.
6. The observations on blast furnace slag indicate that individual particles, which may differ one from another, effect the polishing process. The majority of the particles, having high porosity and rather "soft", are polished significantly. However, pores, micropores and "depressed" areas can still maintain good surface texture of blast furnace slag.

3.6 EFFECTS OF WEATHERING ON THE SURFACE TEXTURE OF THE AGGREGATES

3.6.1 SCOPE OF THE STUDY

The study of weathering influences on the surface texture of the aggregates can be divided into two parts:

a. observation of the weathering using the SEM; and

b. observation of any surface contamination or changes due to weathering using x-ray diffraction (i.e., composition).

In the first part of the weathering study, four types of aggregate: traprock, limestone, Dofasco steel slag and blast furnace slag were subjected to simulated weathering after they have been polished in acoordance with BS 812 (6). Each of these aggregates was submerged in each of four types of solution to simulate weathering process related to the precipitation. These solutions were:

a. distilled water;

b. rainfall water;

c. synthetic rainwater; and

d. 1 percent by weight $CaCl_2$ solution.

3.6.2 PREPARATION OF SOLUTIONS FOR THE WEATHERING PROCESSES

The type, description and/or preparation of the solutions for the weathering processes are as follows:

1. Distilled Water

   Distilled water was obtained from the chemical laboratory of the Engineering Building at McMaster University, Hamilton. Although impurities have been minimized, chemical analysis showed that it contains dissolved CO_2 which makes the water slightly acid (pH = 5.4). The chemical analysis of the distilled water is given in Appendix I.

2. Rainfall Water

   The rainfall water was collected on the roof of the Engineering Building at McMaster University, Hamilton, June 24, 1979. It was a rather long duration rainfall of about 22.4 mm. The chemical analysis showed that it was not really polluted. The pH was about 4.5 which is close to other reports on rainwater analysis in Canada (11). The chemical analysis of the rainfall is given in Appendix I.

3. Synthetic Rainwater

The synthetic rainwater was made in the laboratory. It is a standardized rainfall, which is termed Eastern Urban Rain by ASTM (11).

One litre of Eastern Urban Rain incorporates:

10 ml H_2SO_4;

0.1337 g NH_4Cl; and

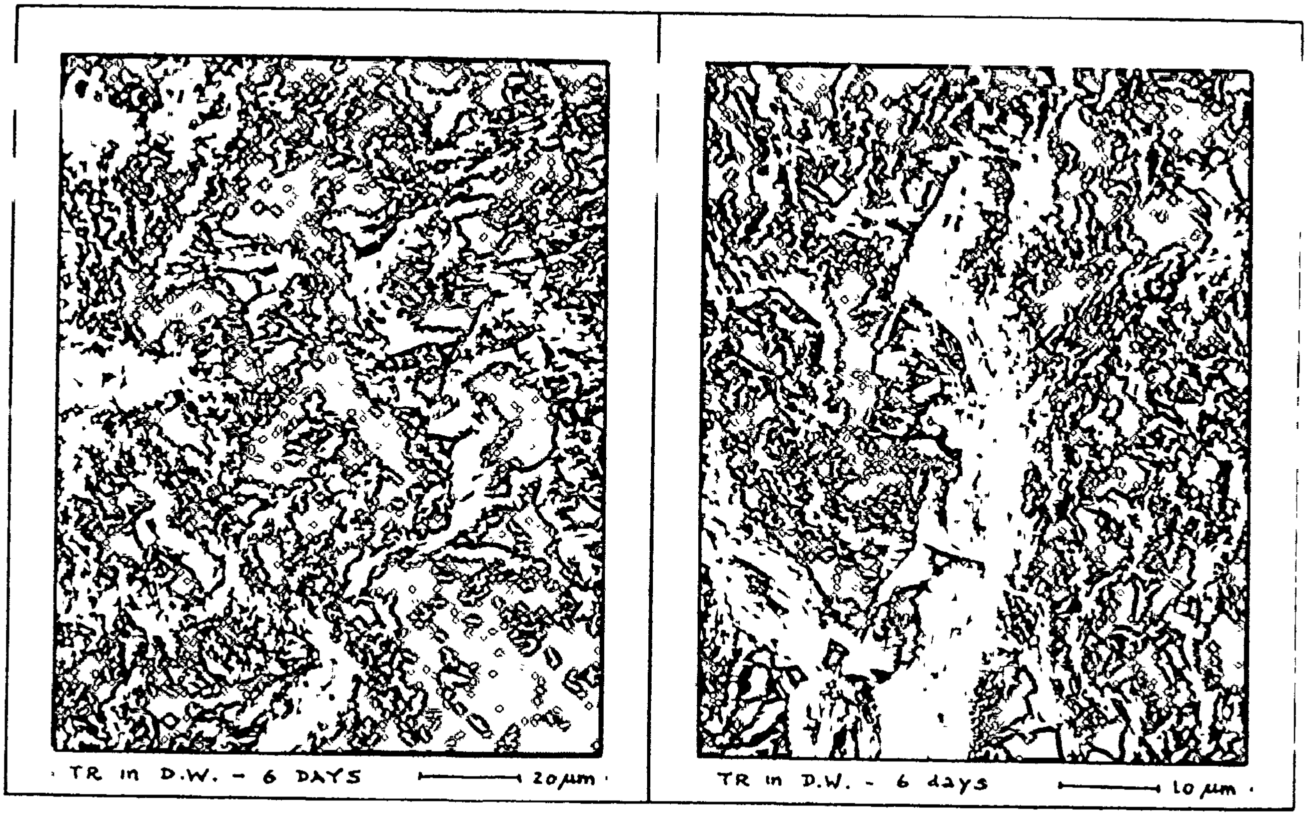
0.5905 g $Ca(NO_3)_2$ 4 H_2O.

4. One percent by weight $CaCl_2$ solution:

$CaCl_2$ is the main component of many commercial chemical ice melters. This was used to simulate the road condition during the winter period.

3.6.3 SAMPLE PREPARATION AND SEM OBSERVATIONS

The four types of aggregates were polished in accordance with BS 812 (6). Then, selected samples were taken from the polished test coupons and submerged in each of four types of solution. After 6 and 15 days in these solutions, the aggregates were then examined in the SEM. Typical photomicrographs, obtained using the SEM are given in Figures 19 to 41. For each aggregate, photomicrographs were taken at about X50, X500, X1000 and X2000 magnifications.



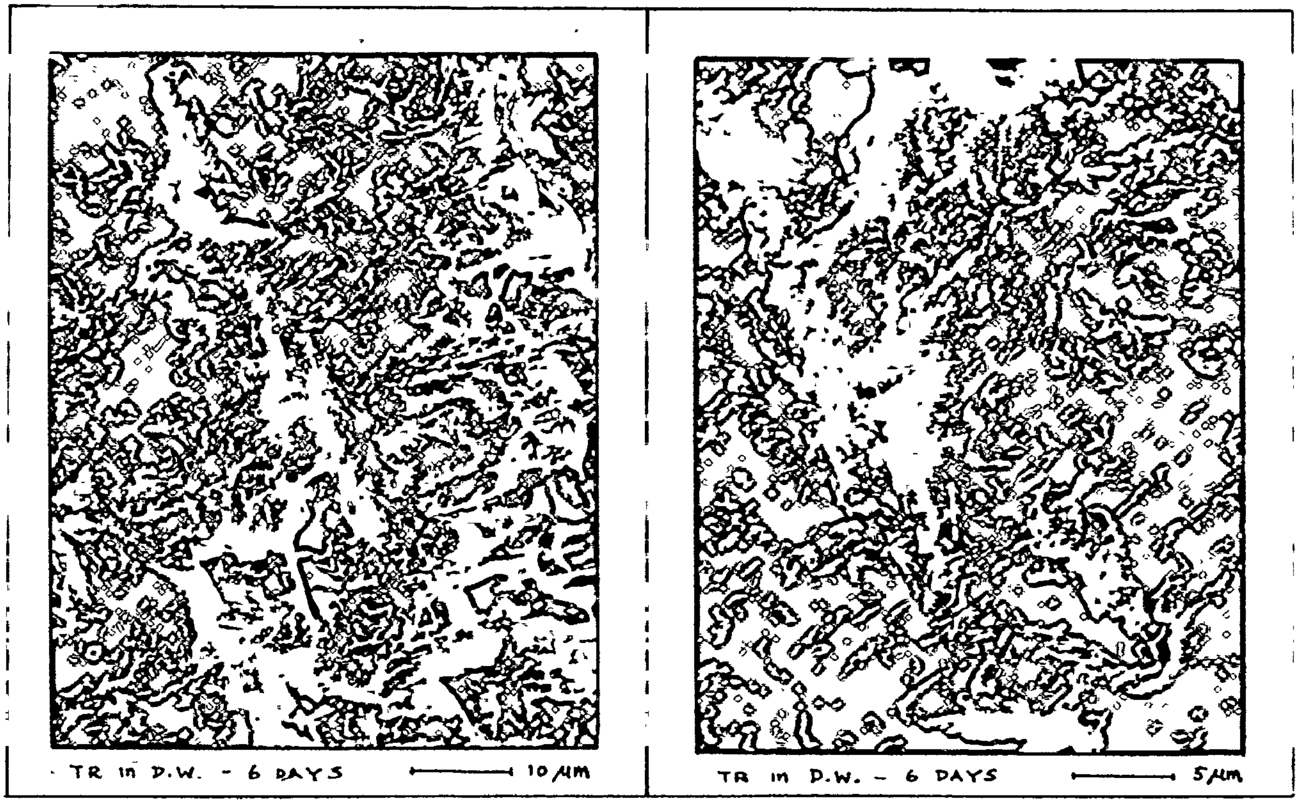
a. X660

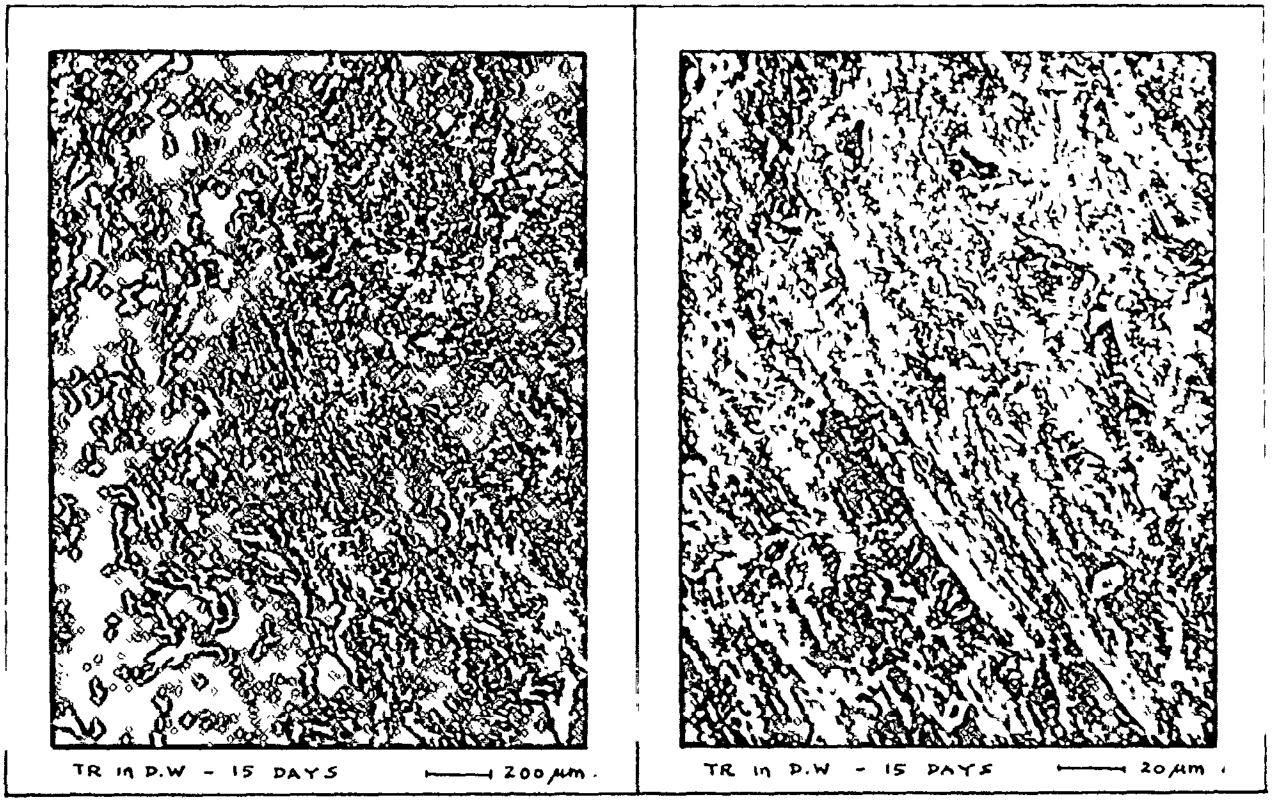
b. X1320

Figure 19. Traprock in Distilled Water: 6 Days

c. X1350

d. X2670

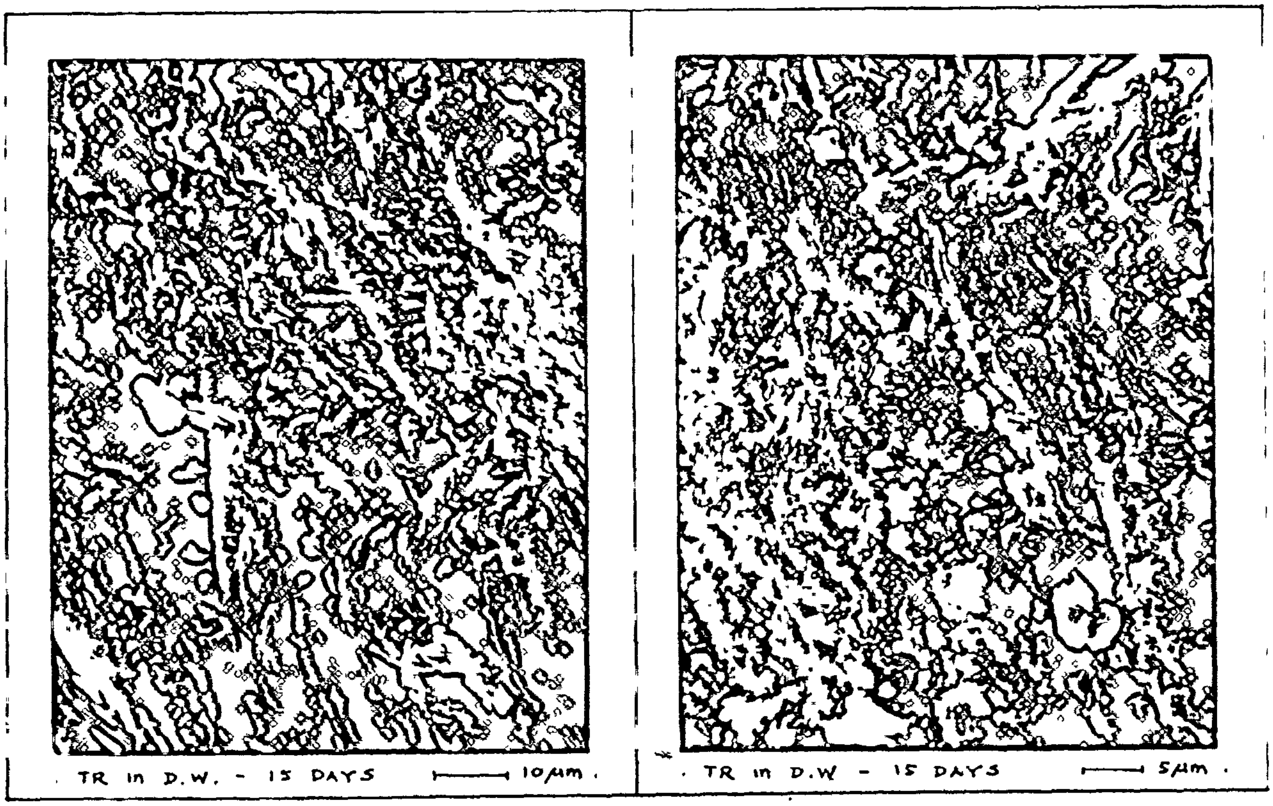


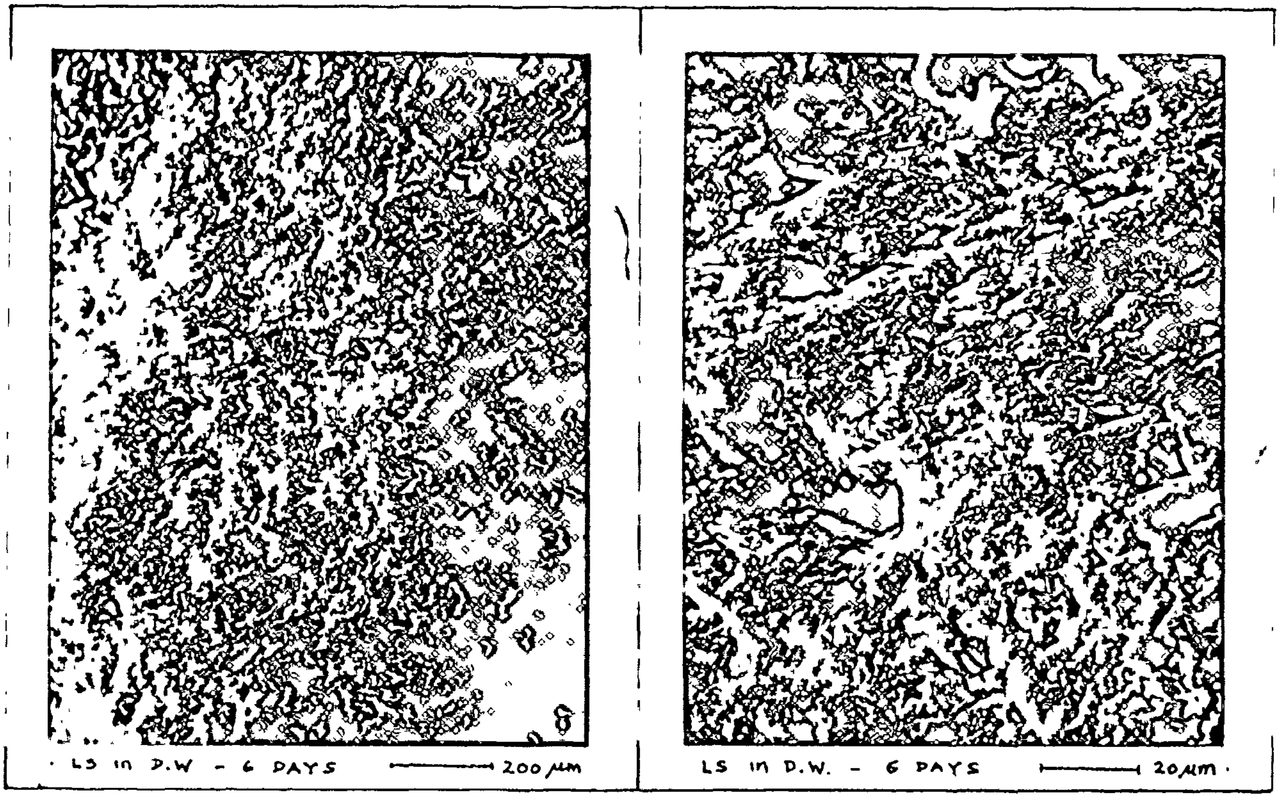


a. X45 b. X450

Figure 20. Traprock in Distilled Water: 15 days

c. X1000 d. X1700

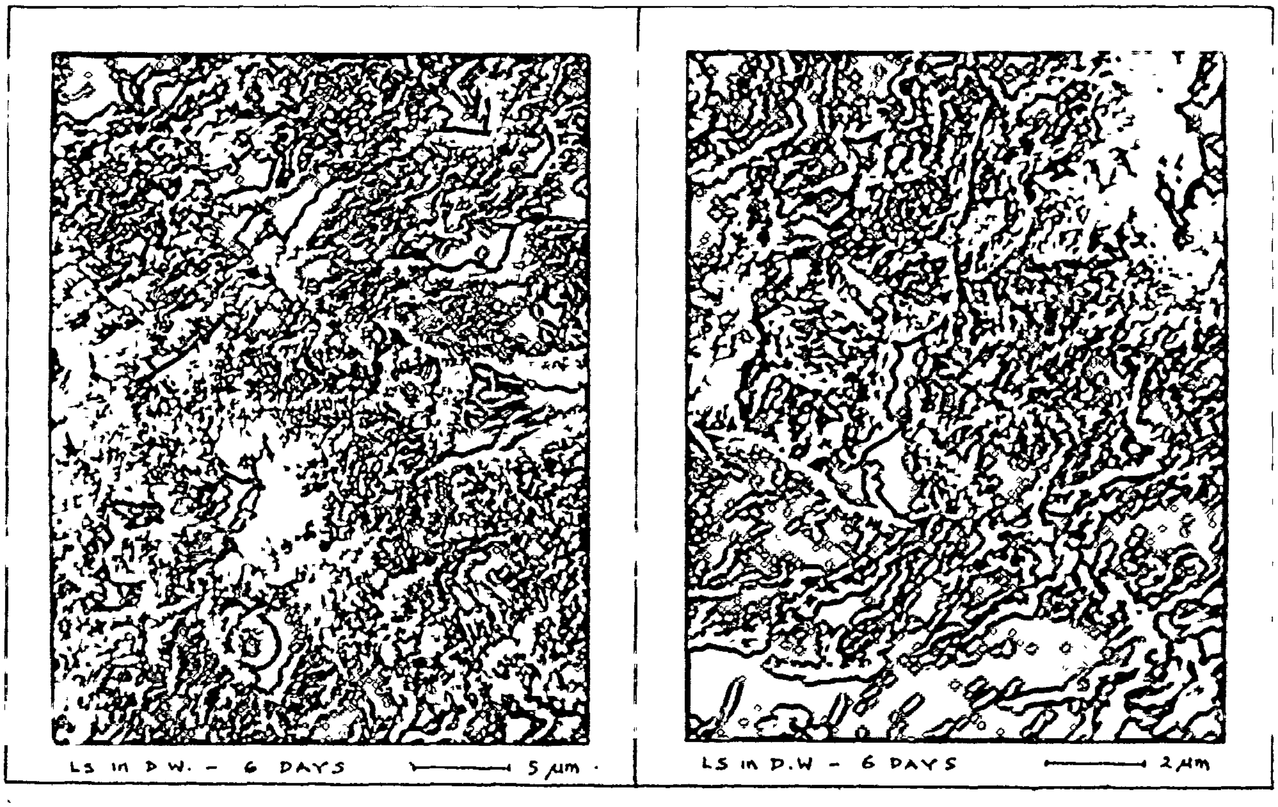


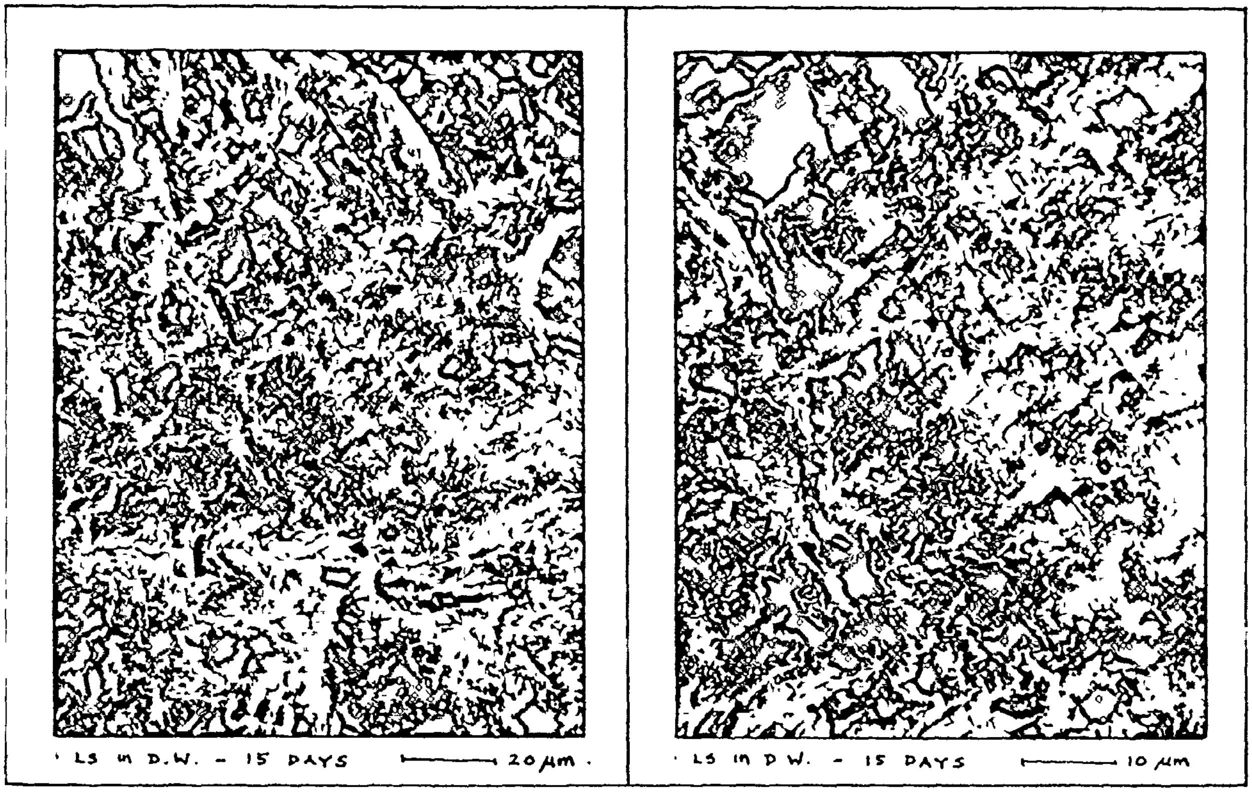


a. X67 b. X670

Figure 21. Limestone in Distilled Water: 6 Days

c. X2700 d. X6750

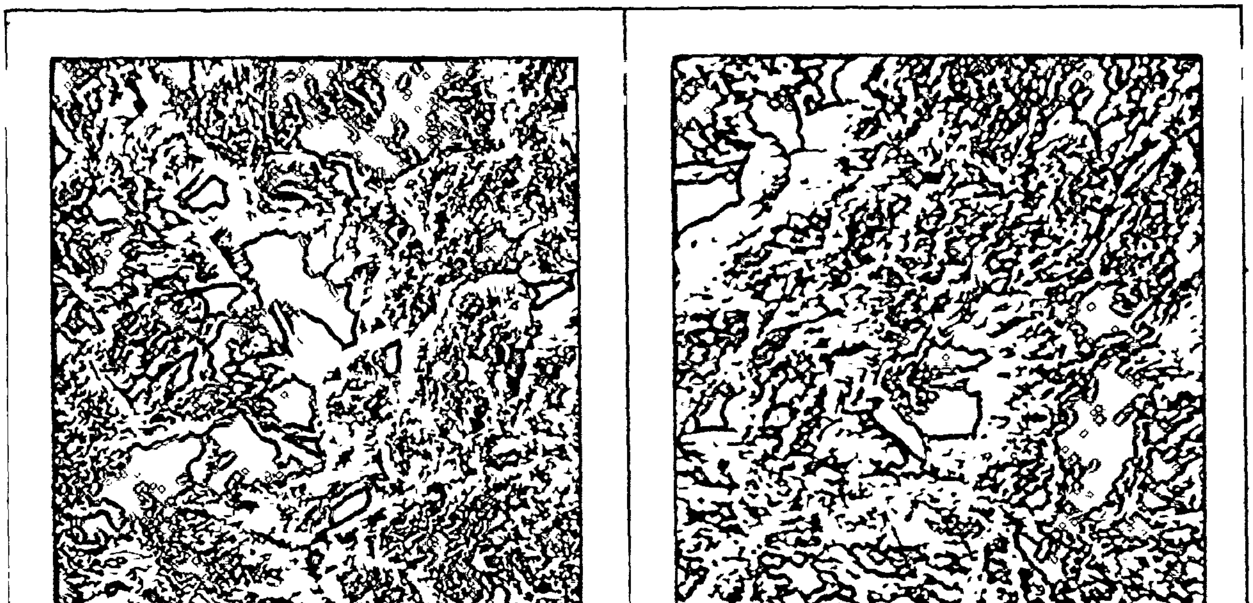


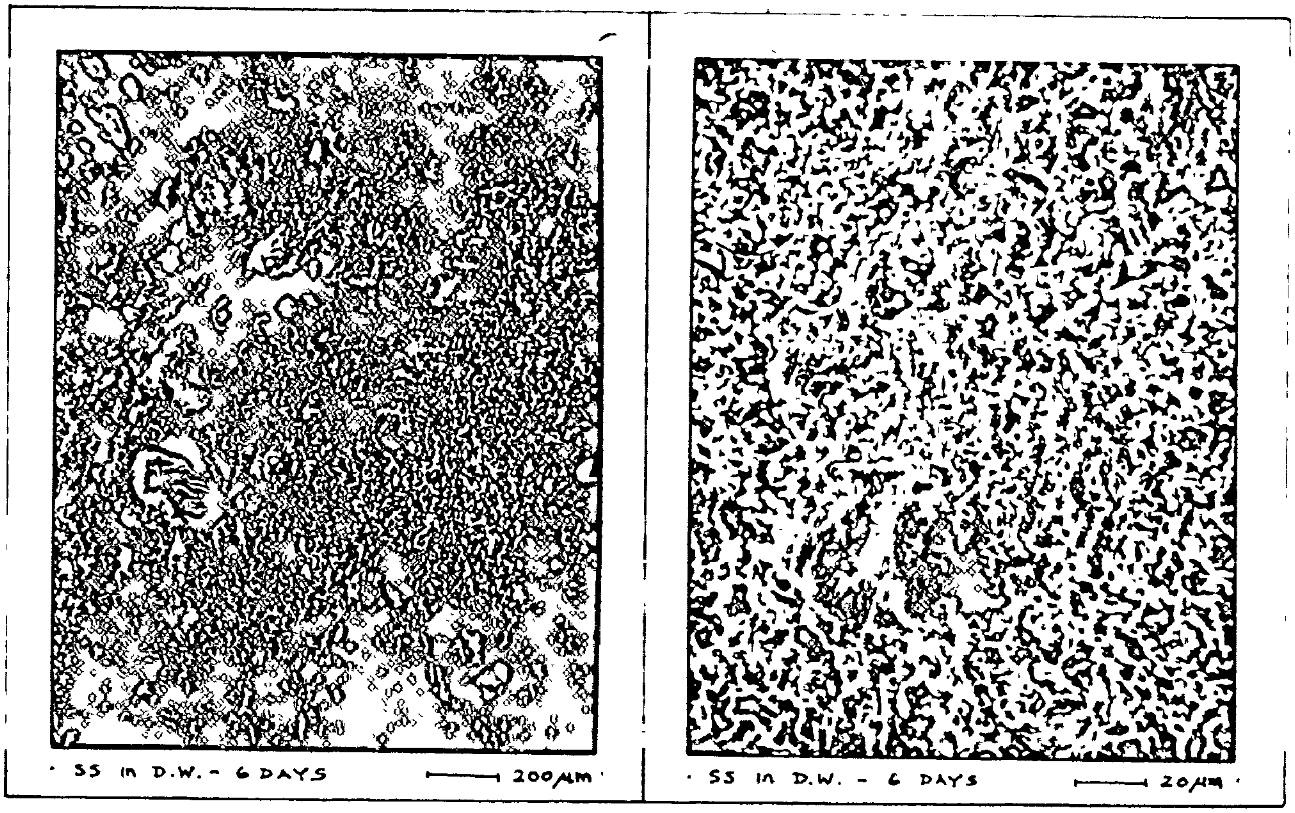


a. X640 b. X1290

Figure 22. Limestone in Distilled Water: 15 Days

c. X1300 d. X2600

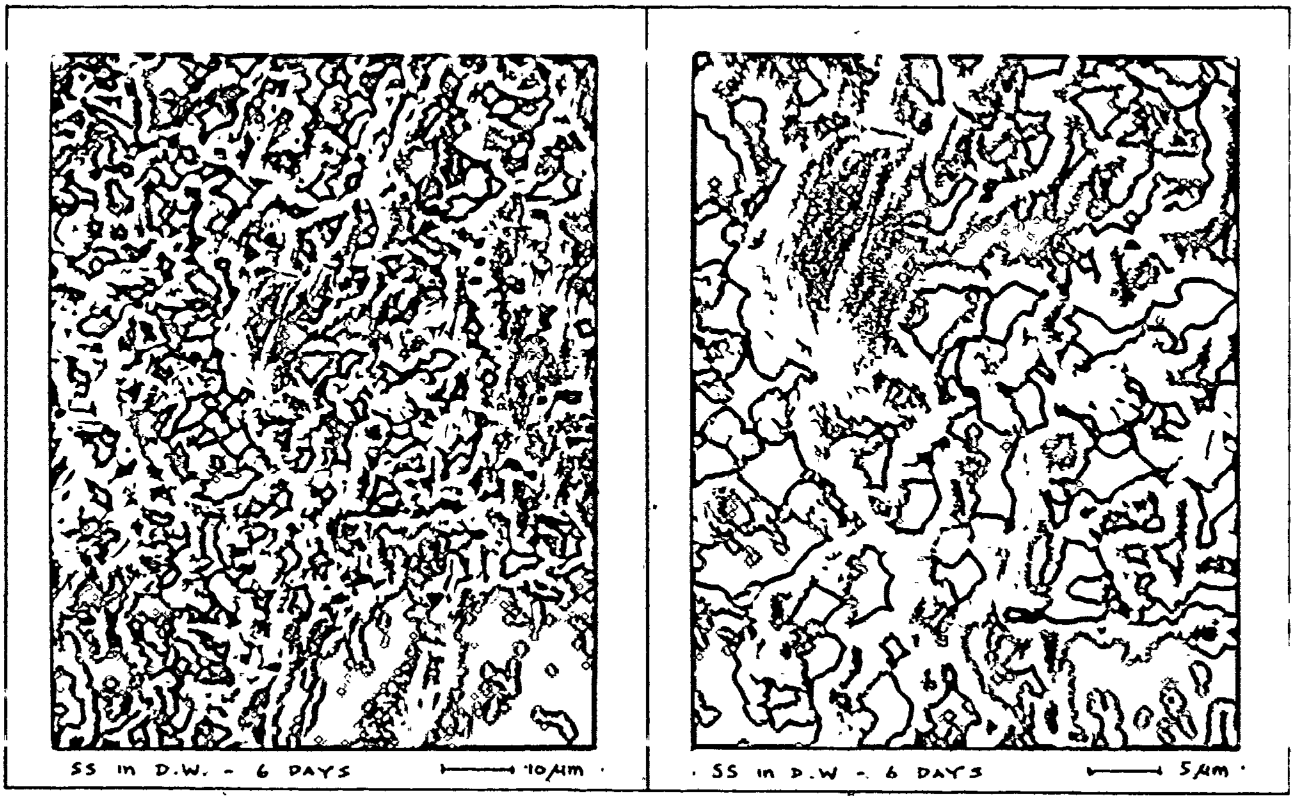


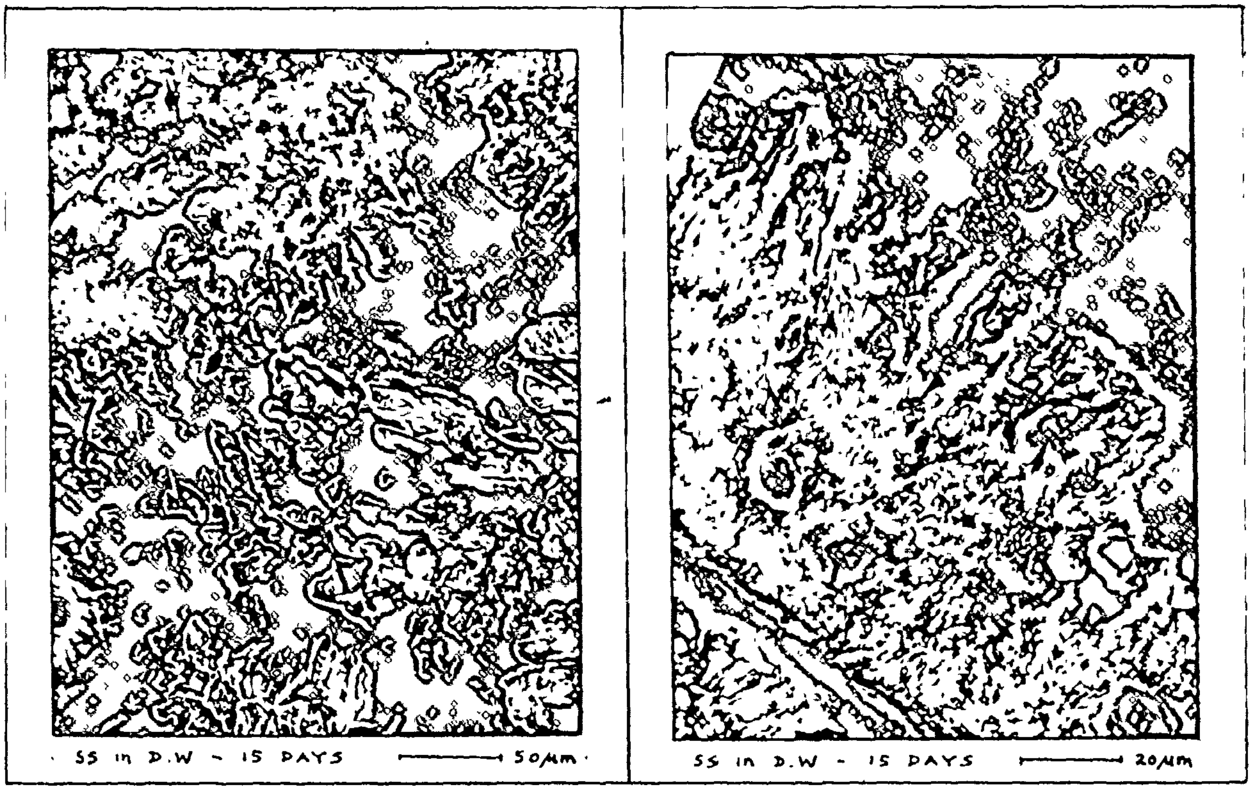


a. X48 b. X480

Figure 23. Steel Slag in Distilled Water: 6 Days

c. X960 d. X1930

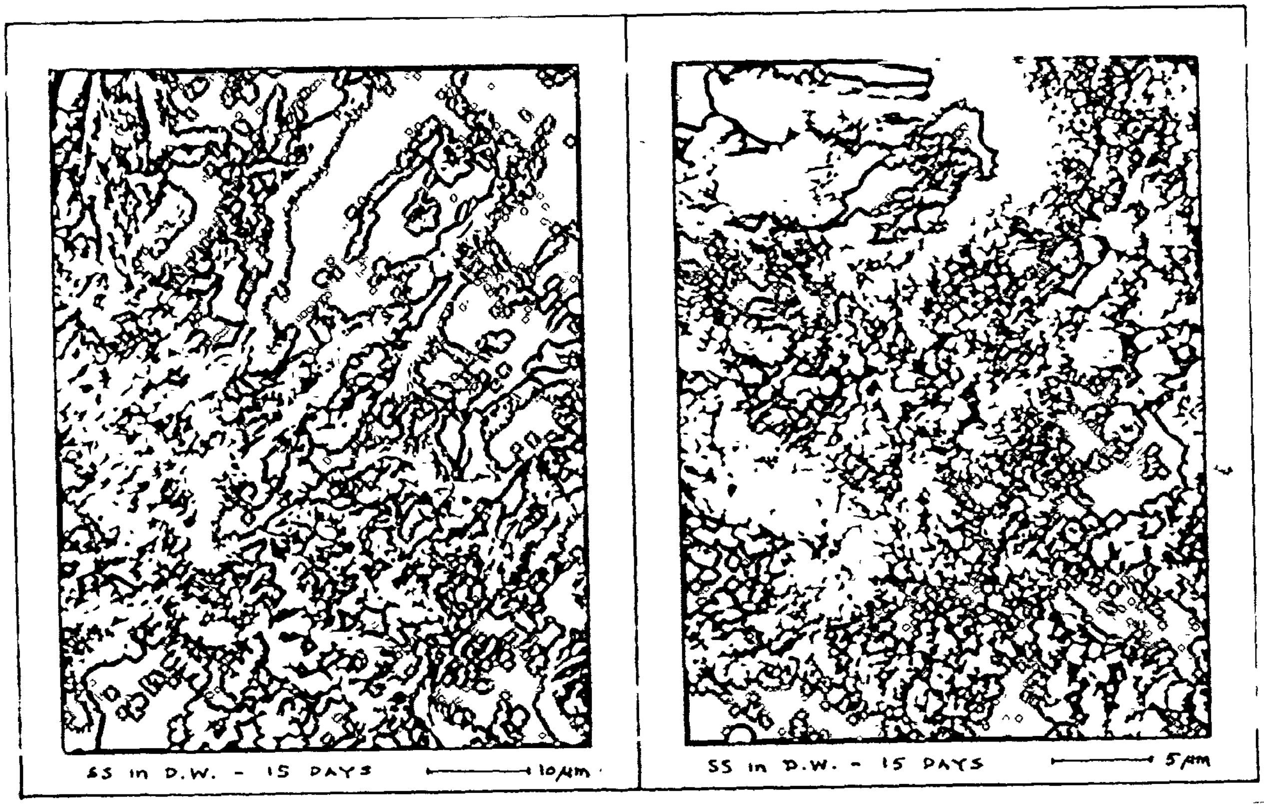


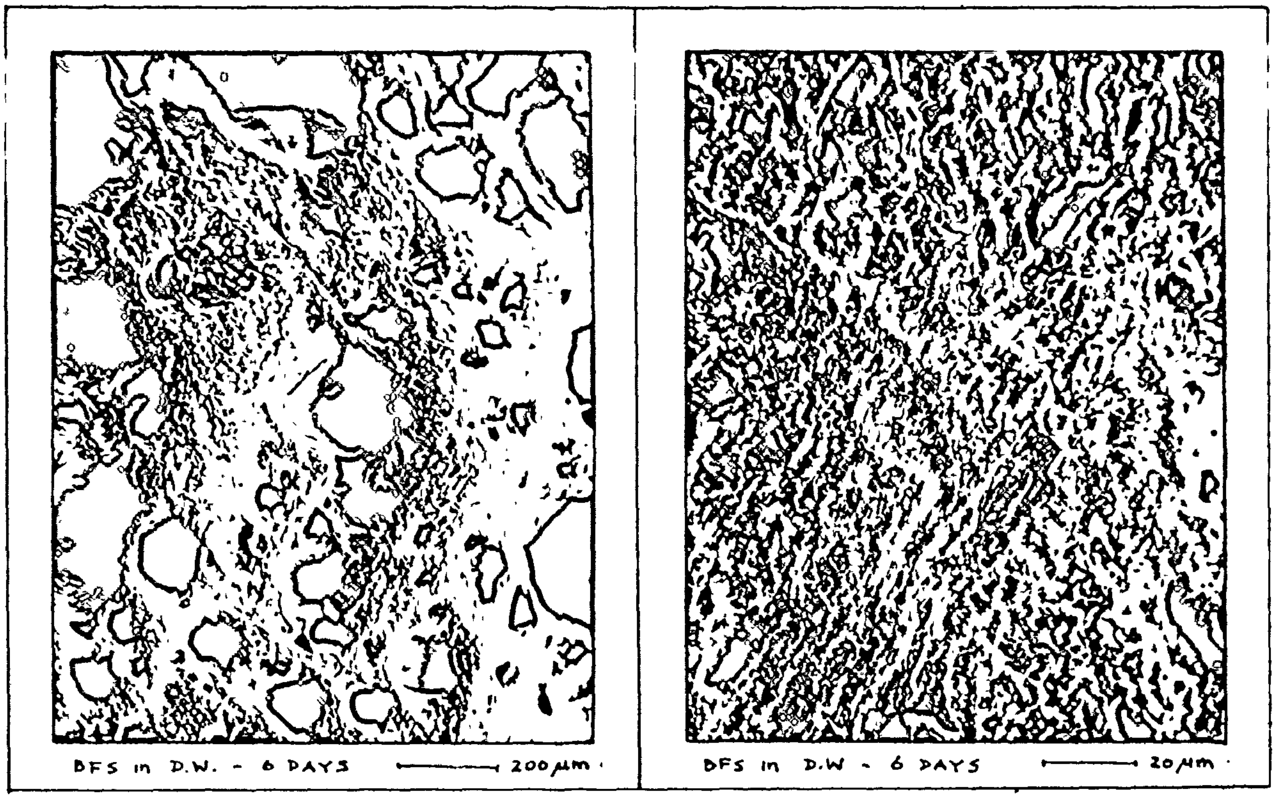


a. X280 b. X700

Figure 24. Steel Slag in Distilled Water: 15 Days

c. X1400 d. X2800

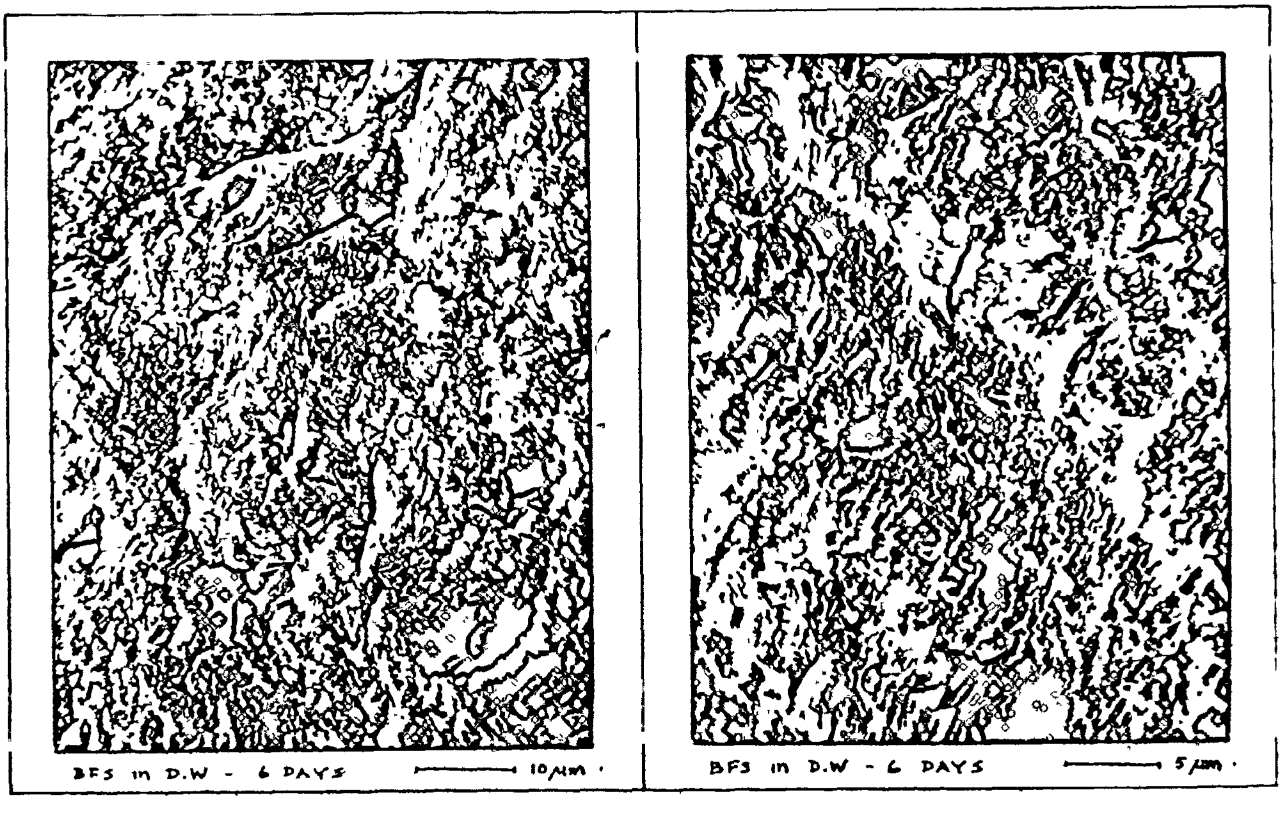


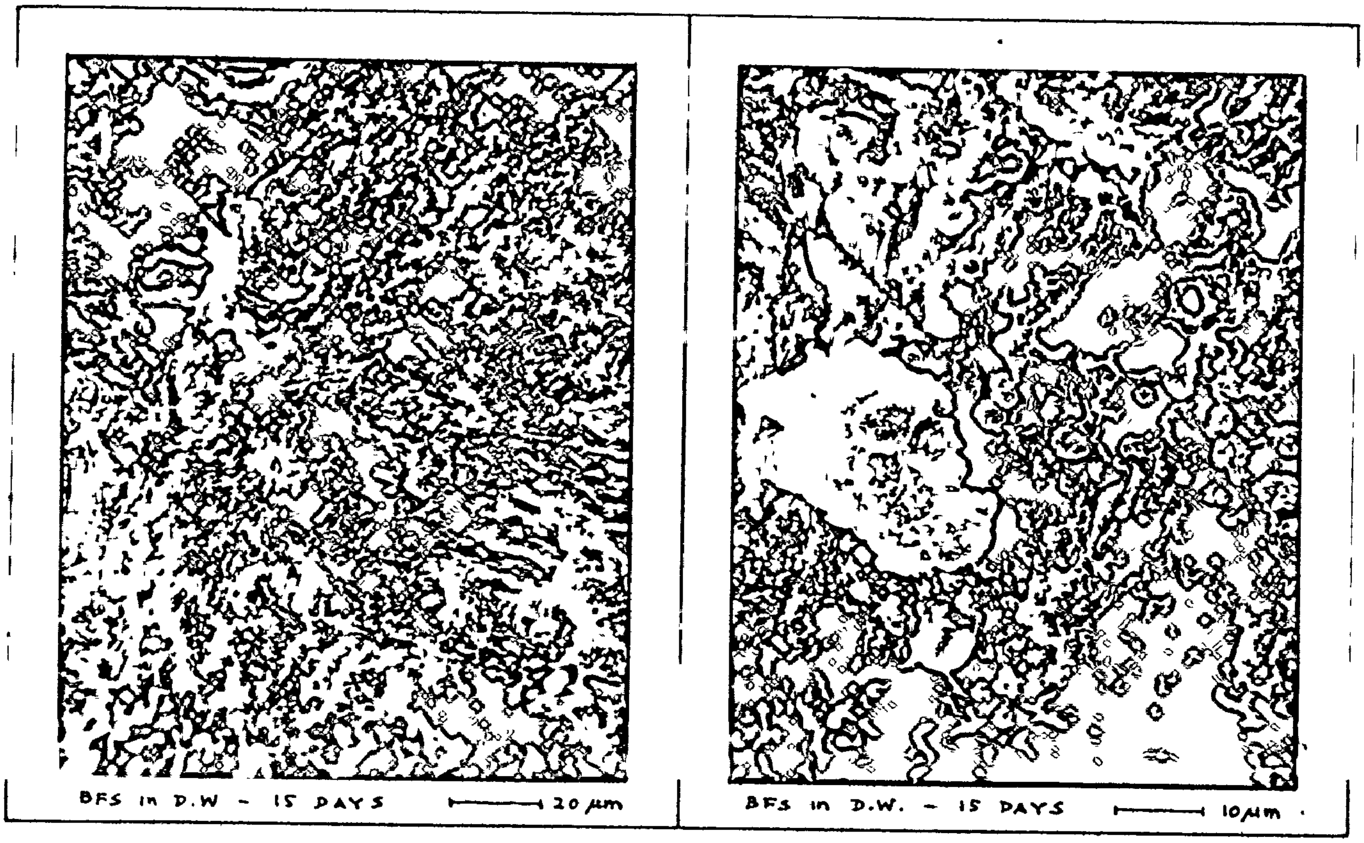


a. X67 b. X650

Figure 25. Blast Furnace Slag in Distilled Water: 6 Days

c. X1350 d. X2600

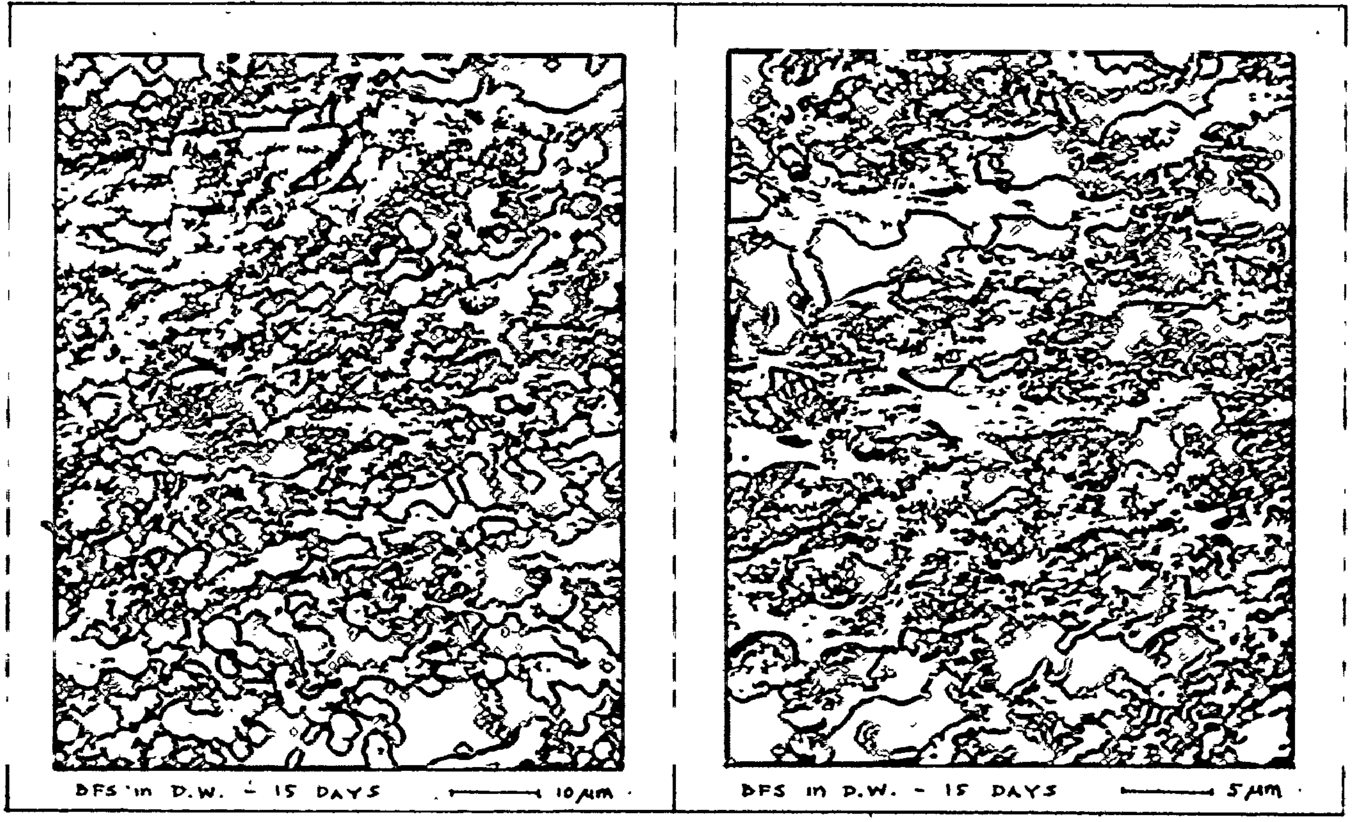


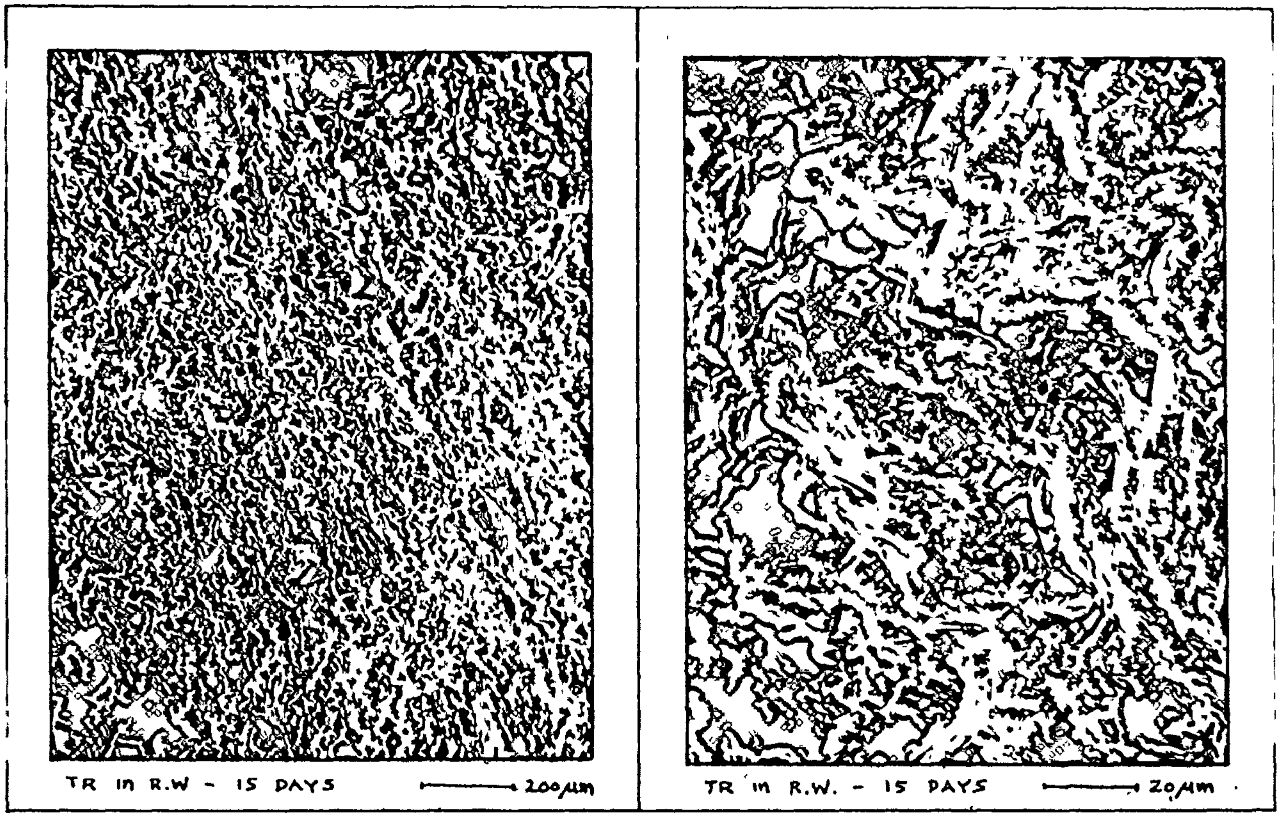


a. X580 b. X1160

Figure 26. Blast Furnace Slag in Distilled Water: 15 Days

c. X1150 d. X2300





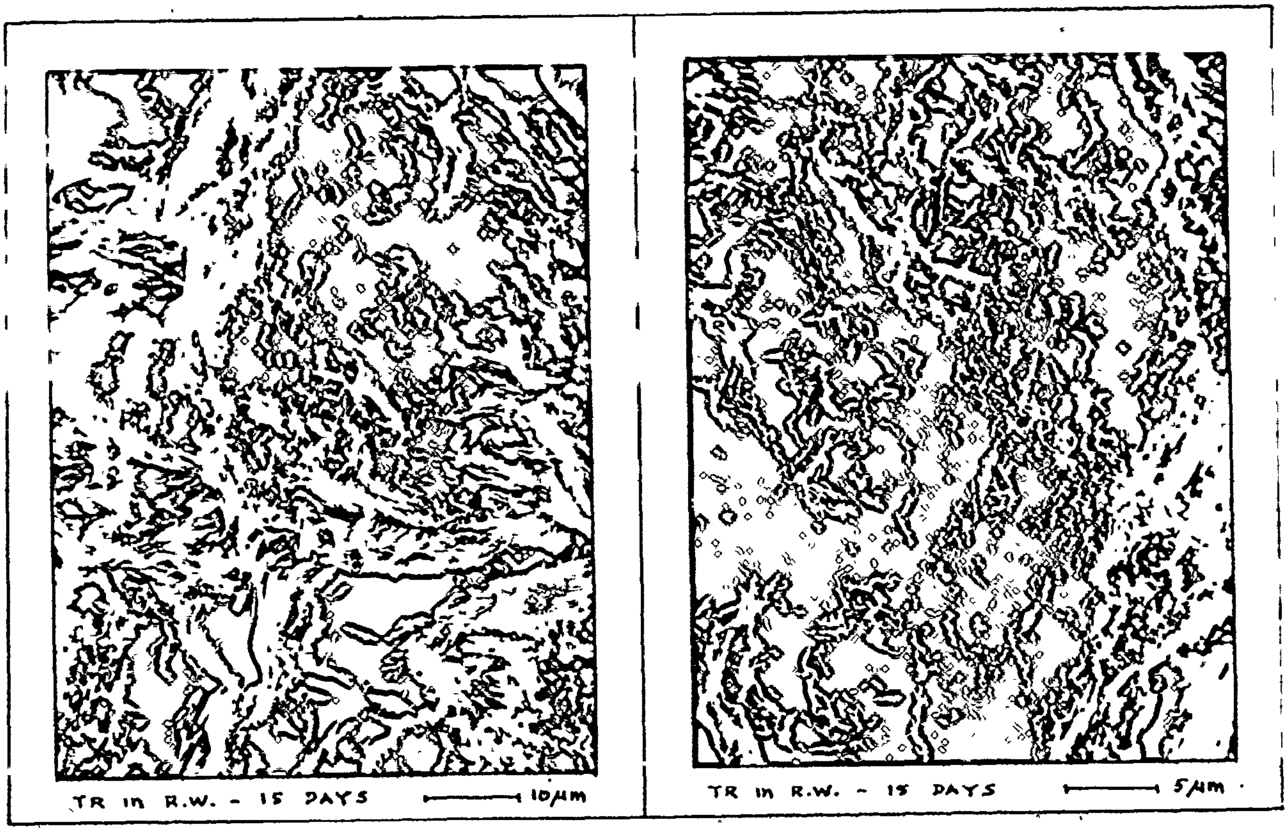
a. X64

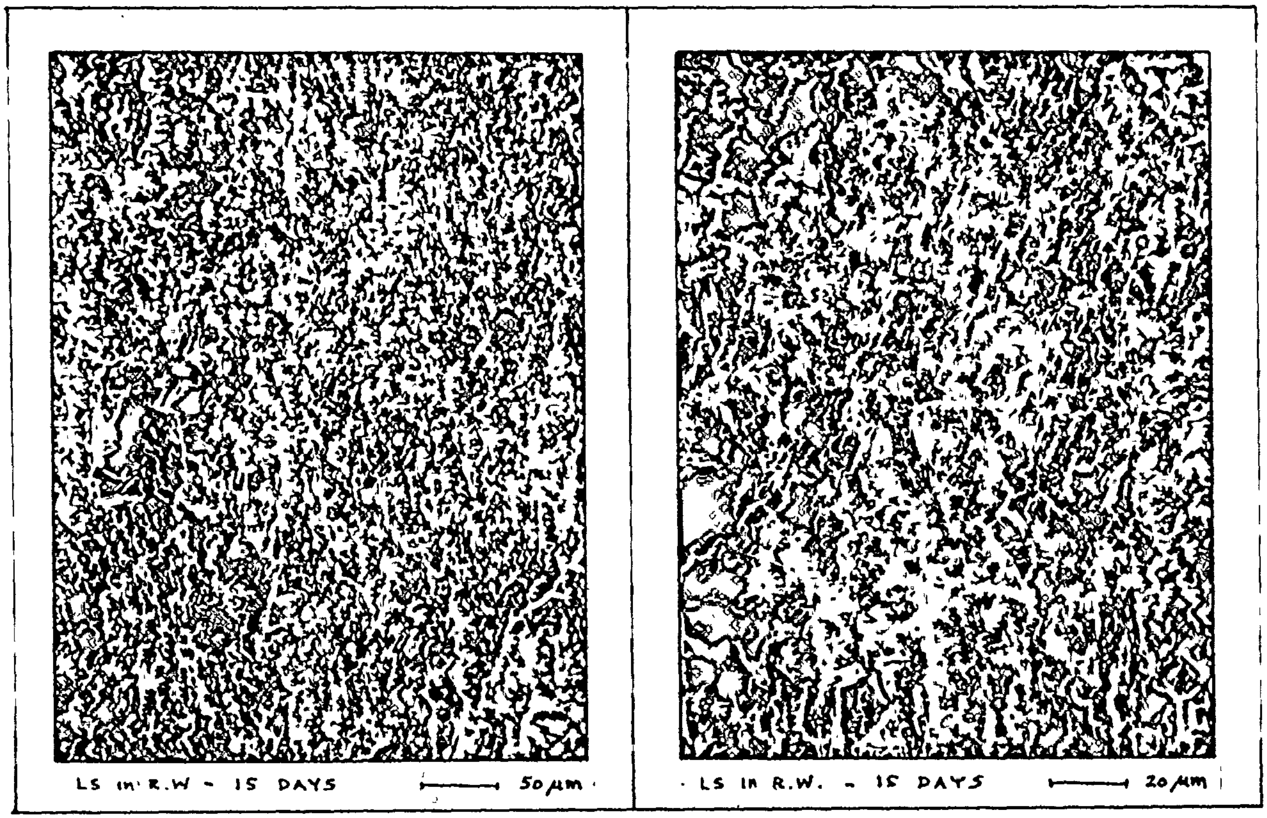
b. X640

Figure 27. Traprock in Rainfall Water: 15 Days

c. X1280

d. X2520

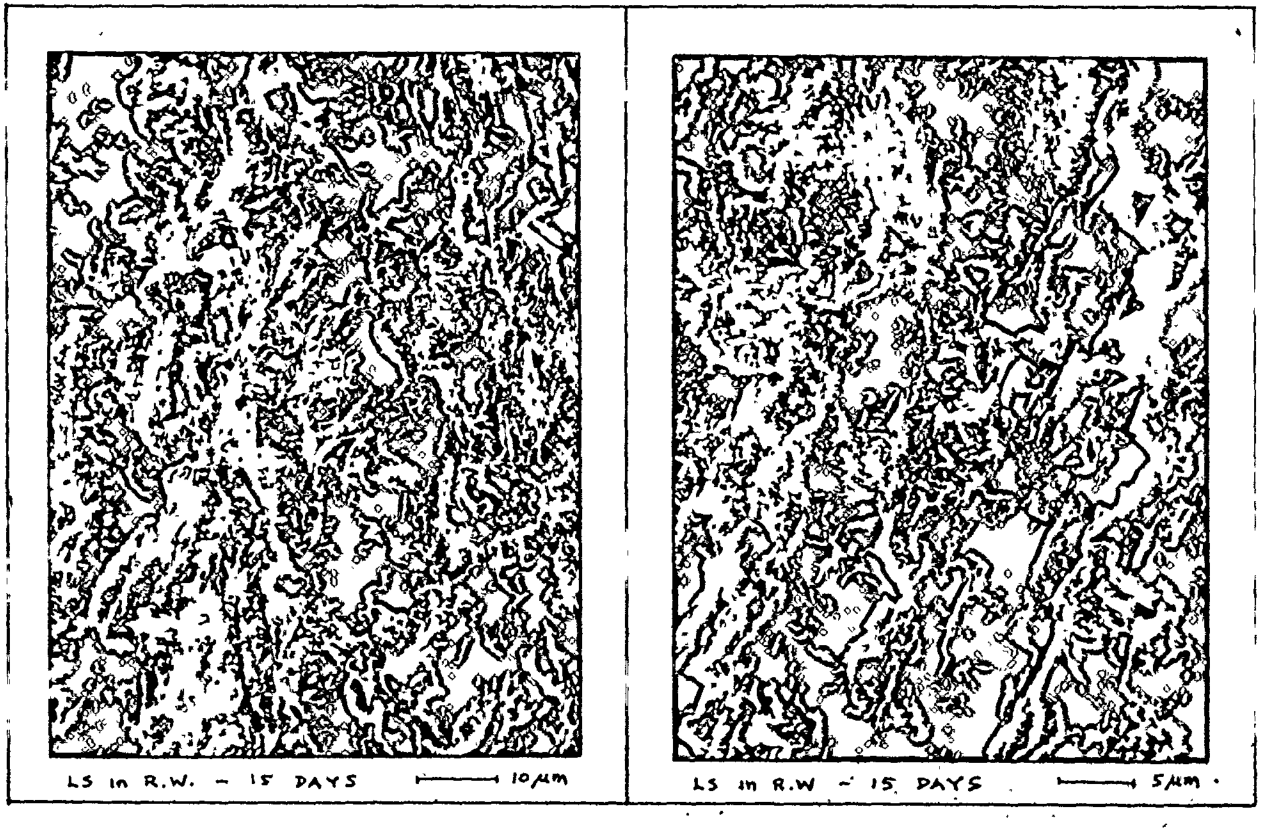


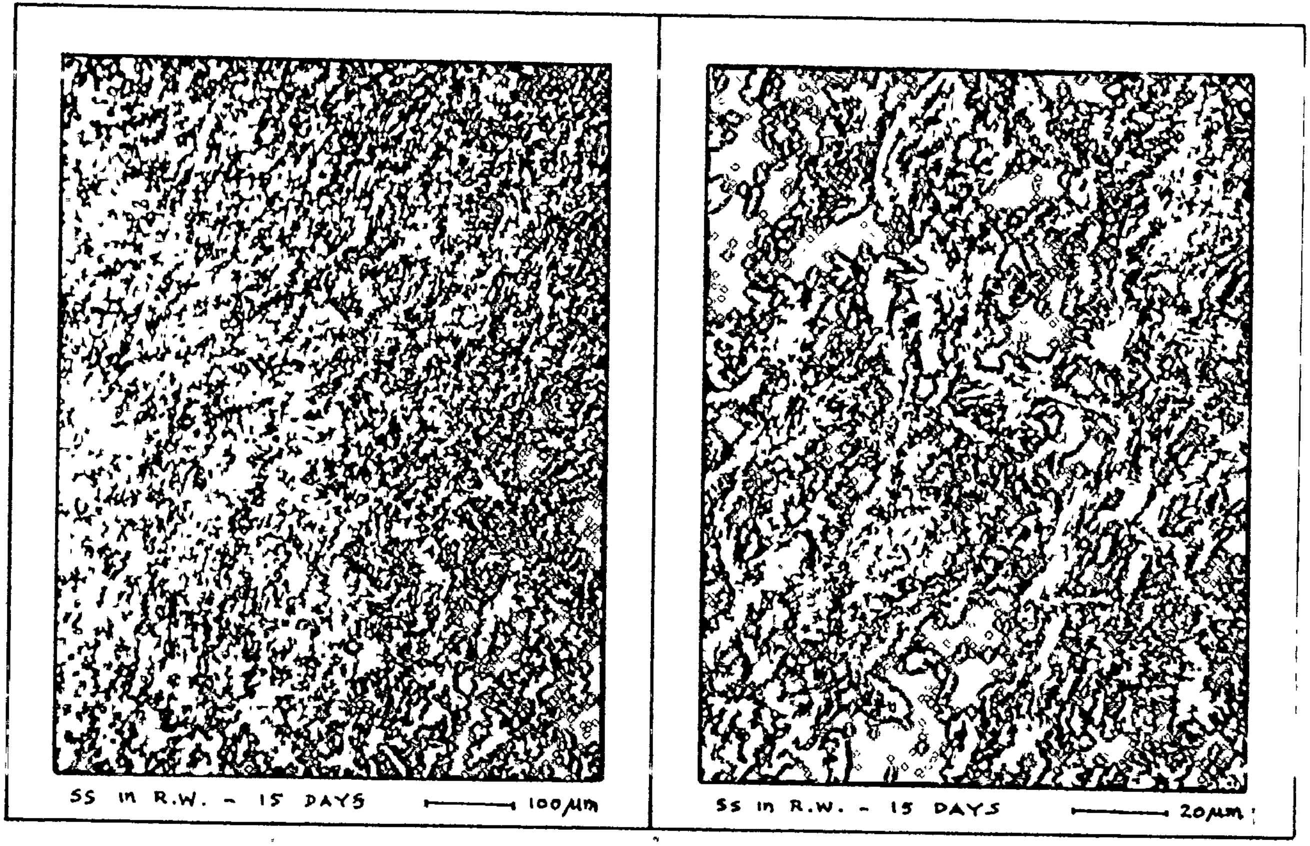


a. X210 b. X525

Figure 28. Limestone in Rainfall Water: 15 Days

c. X1100 d. X2100

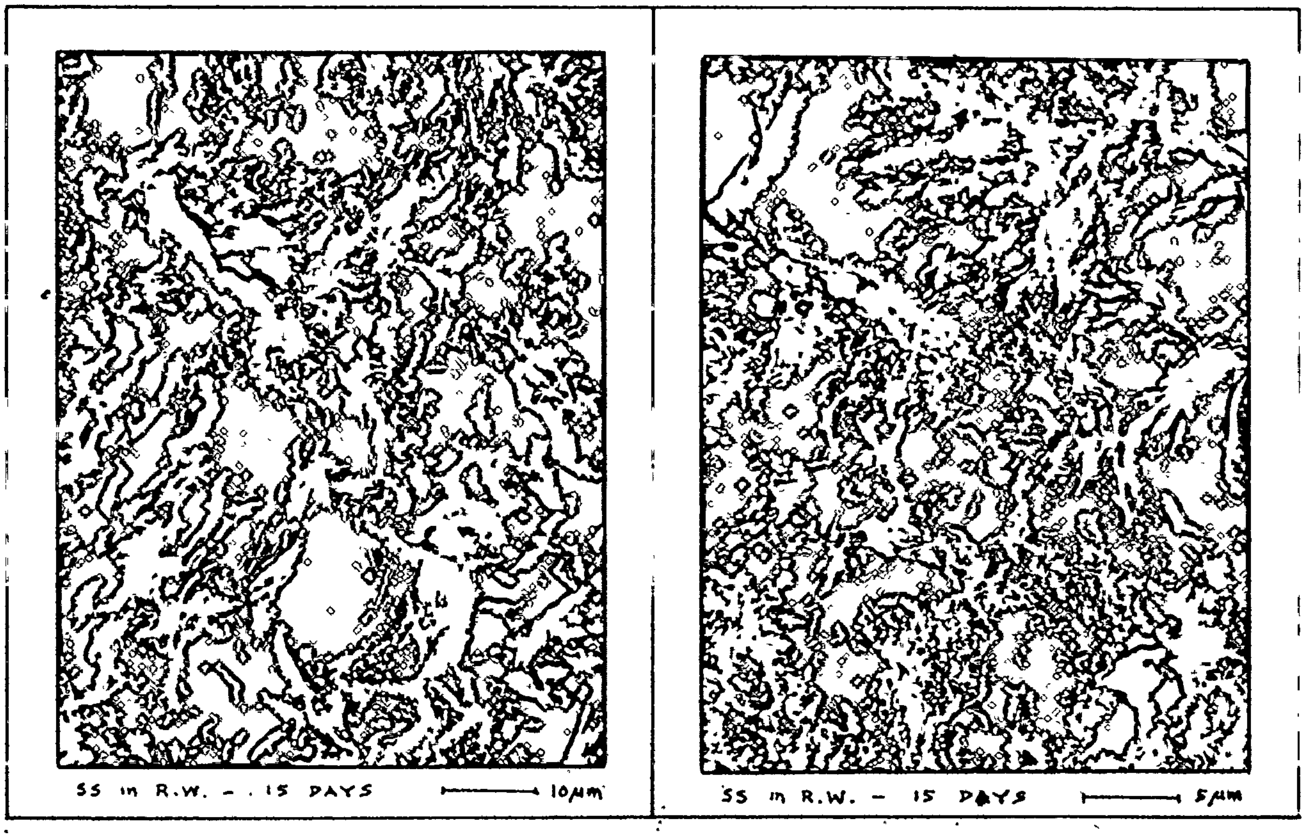


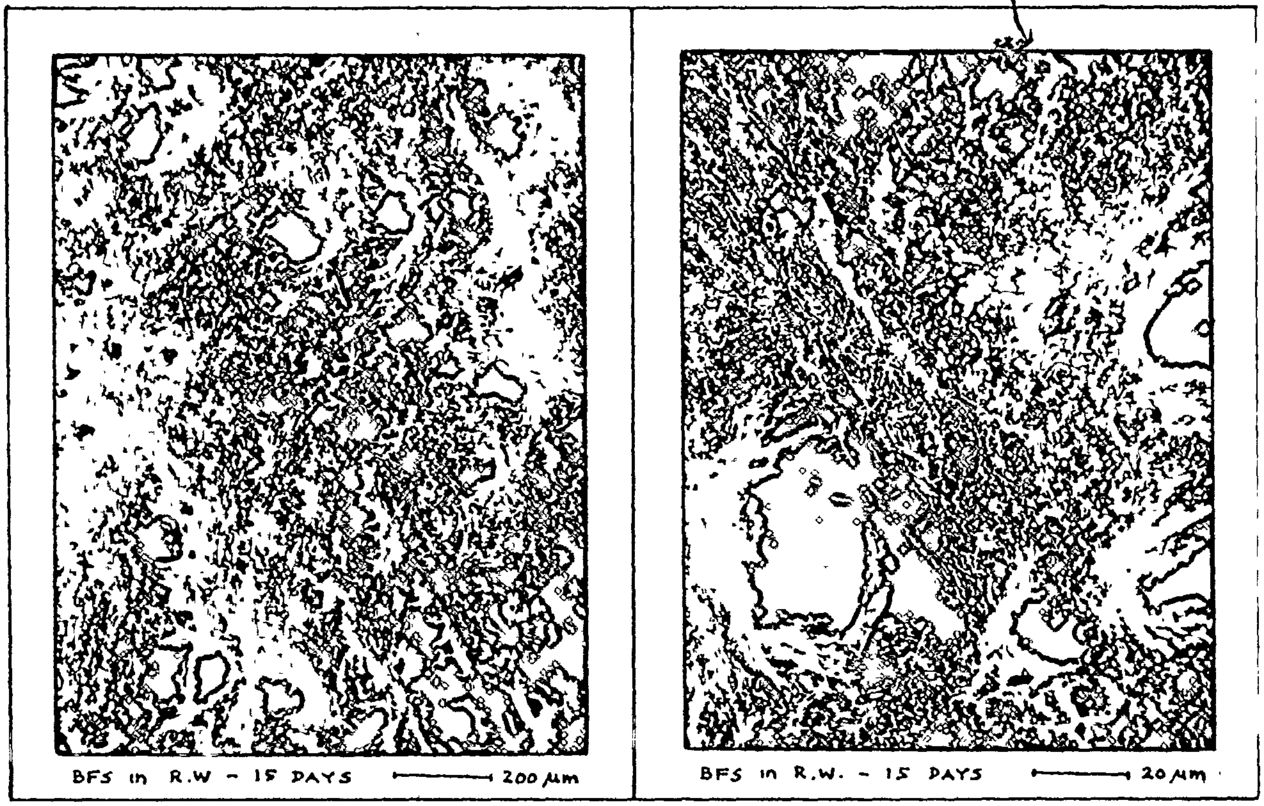


a. X120 b. X650

Figure 29. Steel Slag in Rainfall Water: 15 Days

c. X1300 d. X2600

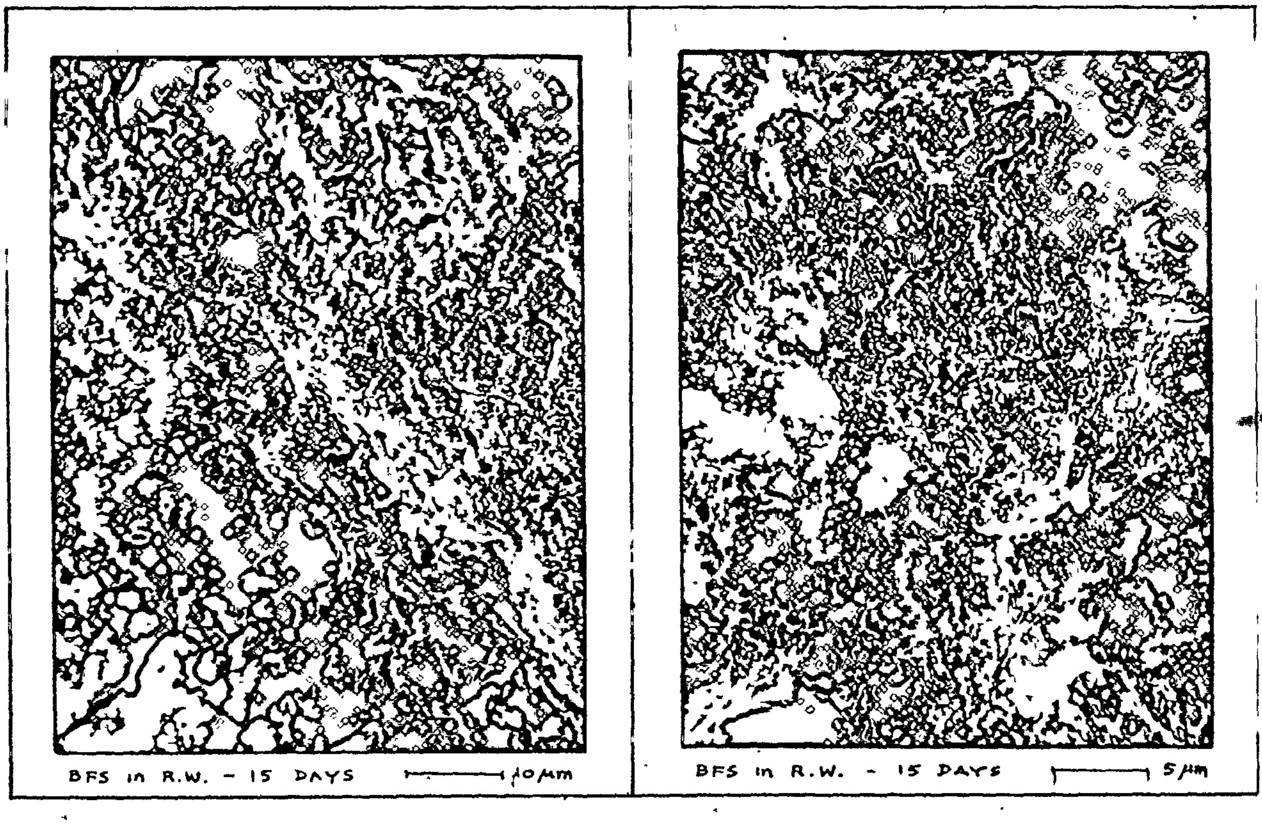


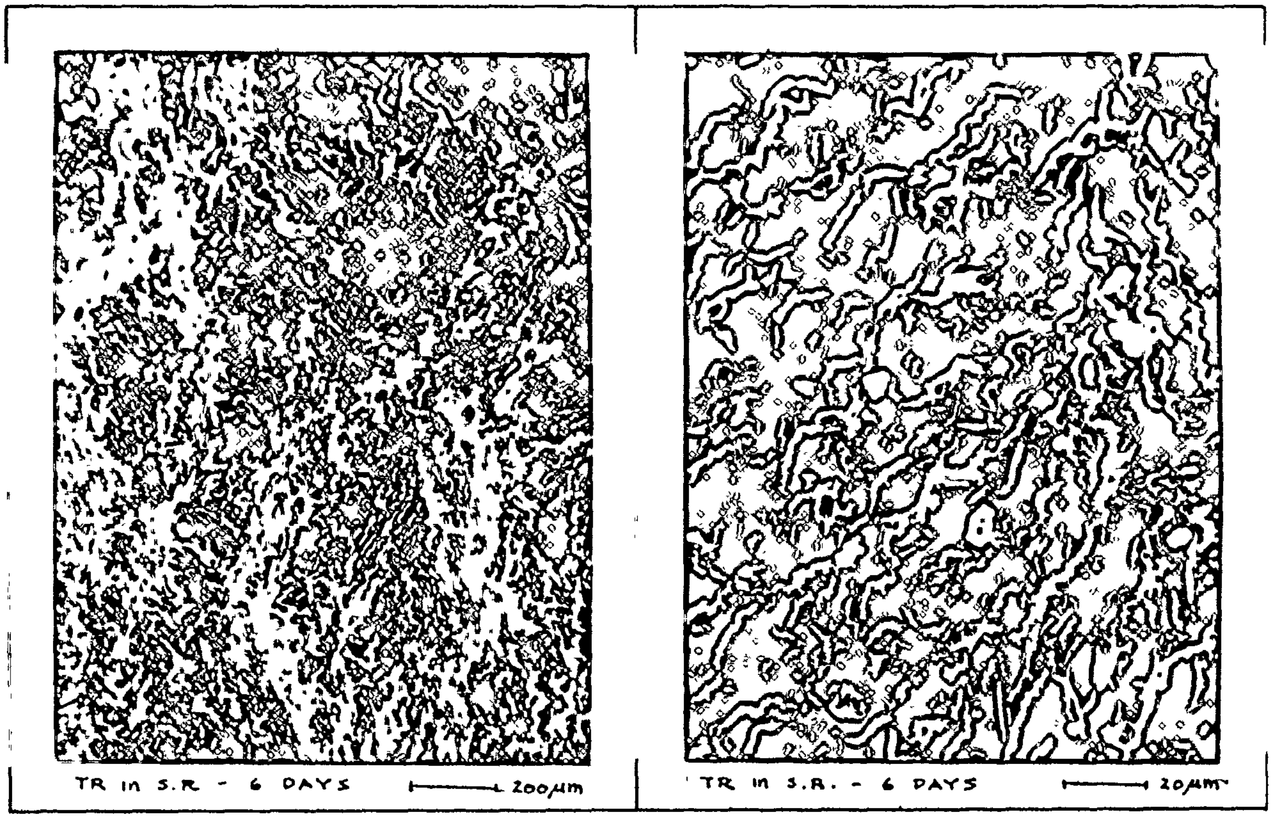


a. X67 b. X670

Figure 30. Blast Furnace Slag in Rainfall Water: 15 Days

c. X1340 d. X2680

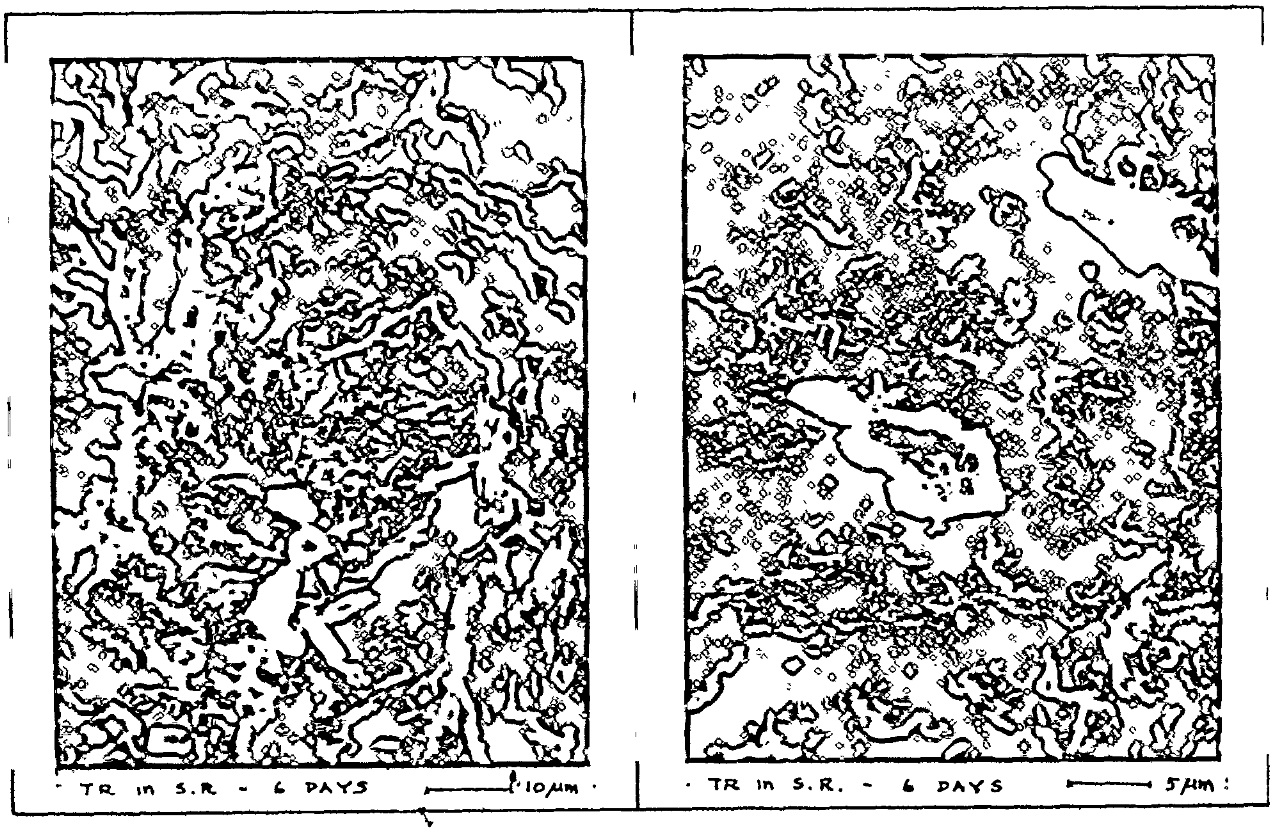


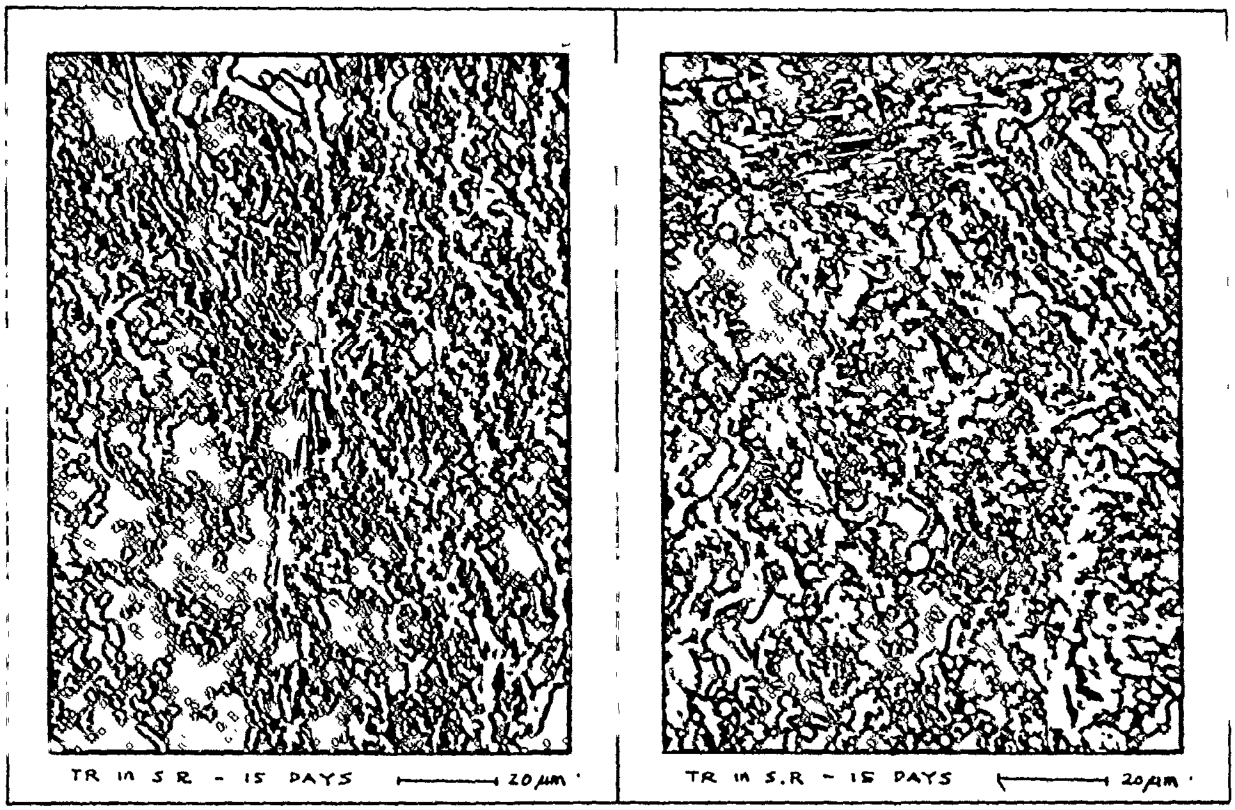


a. X59 b. X575

Figure 31. Traprock in Synthetic Rain: 6 Days

c. X1150 d. X2300

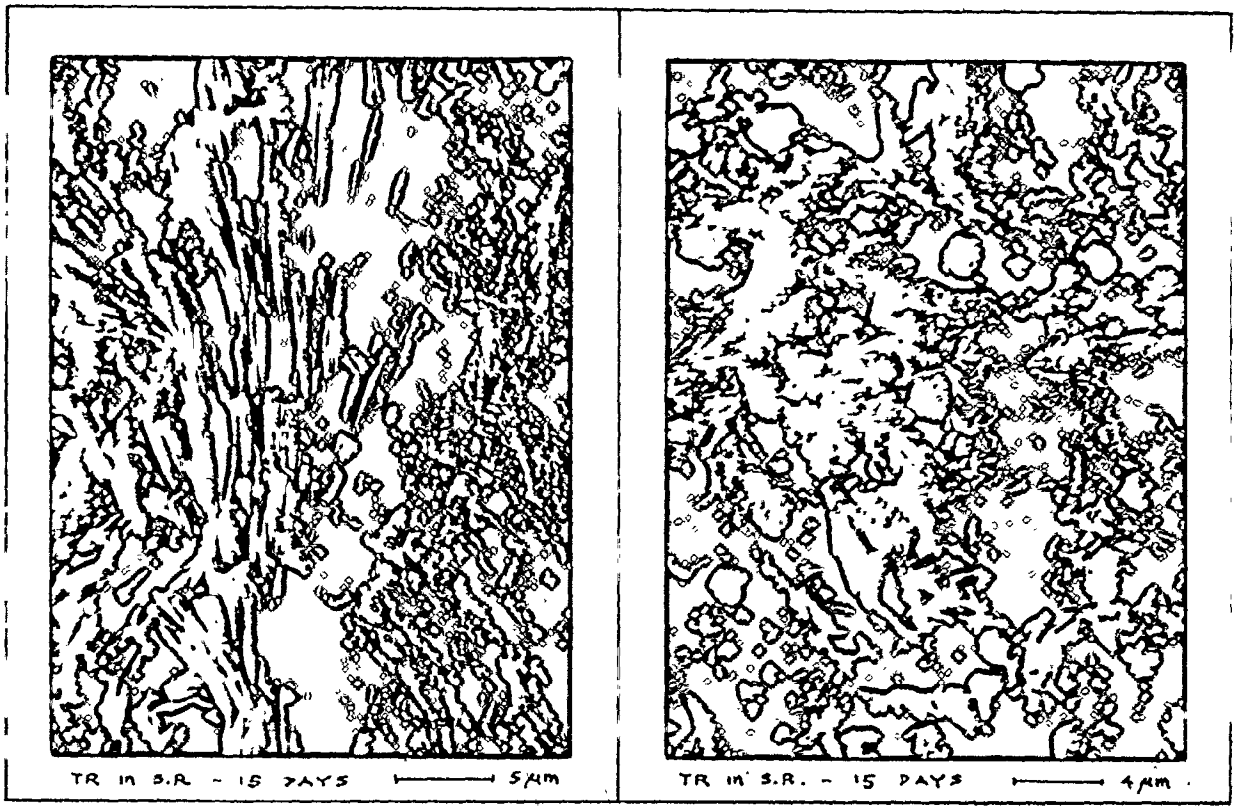


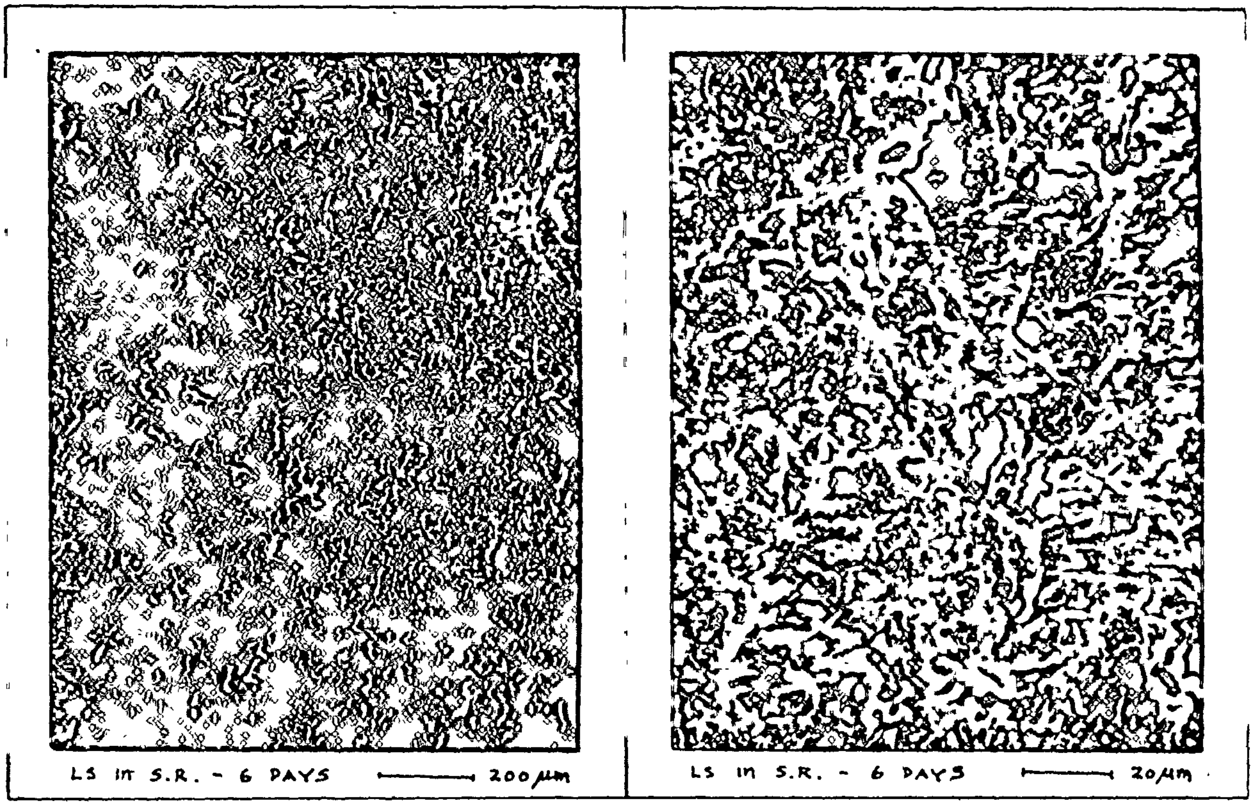


a. X700 b. X780

Figure 32. Traprock in Synthetic Rain: 15 Days

c. X2800 d. X3150

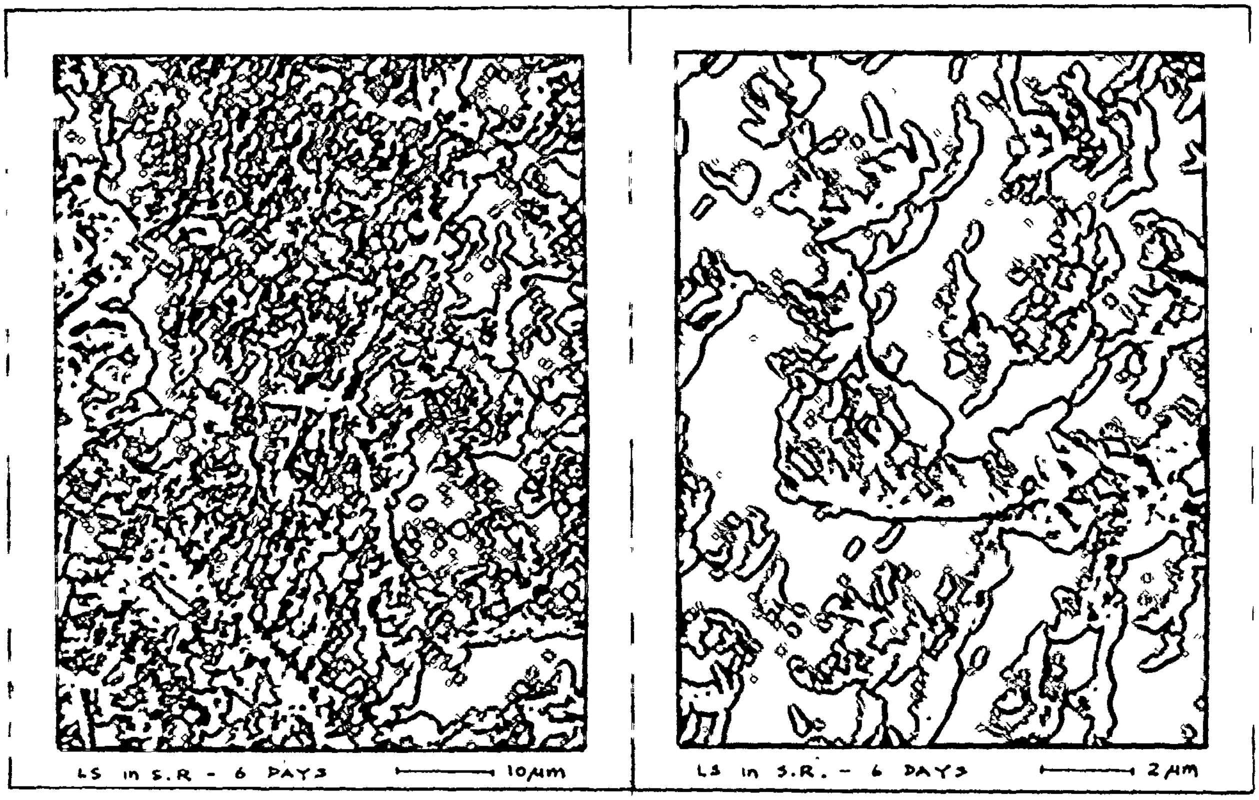


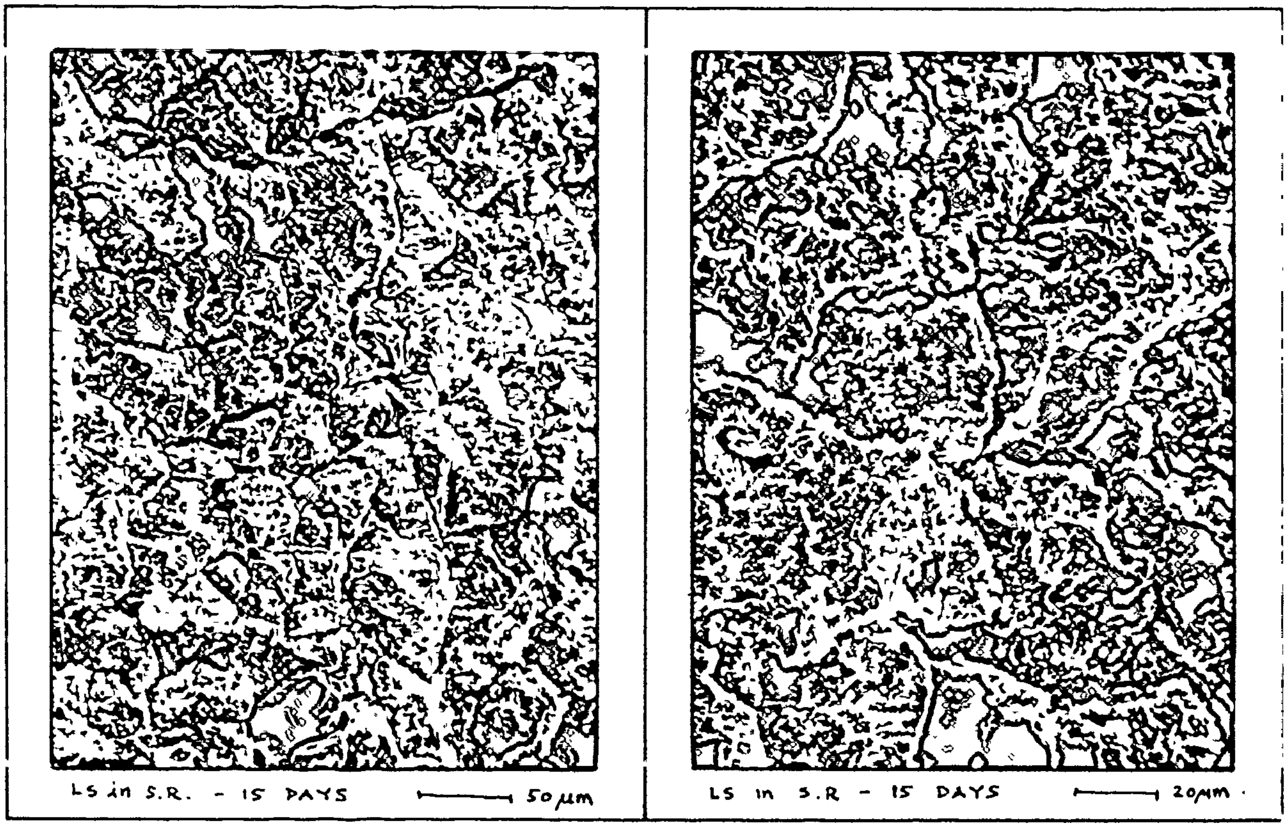


a. X65 b. X640

Figure 33. Limestone in Synthetic Rain: 6 Days

c. X1320 d. X6500

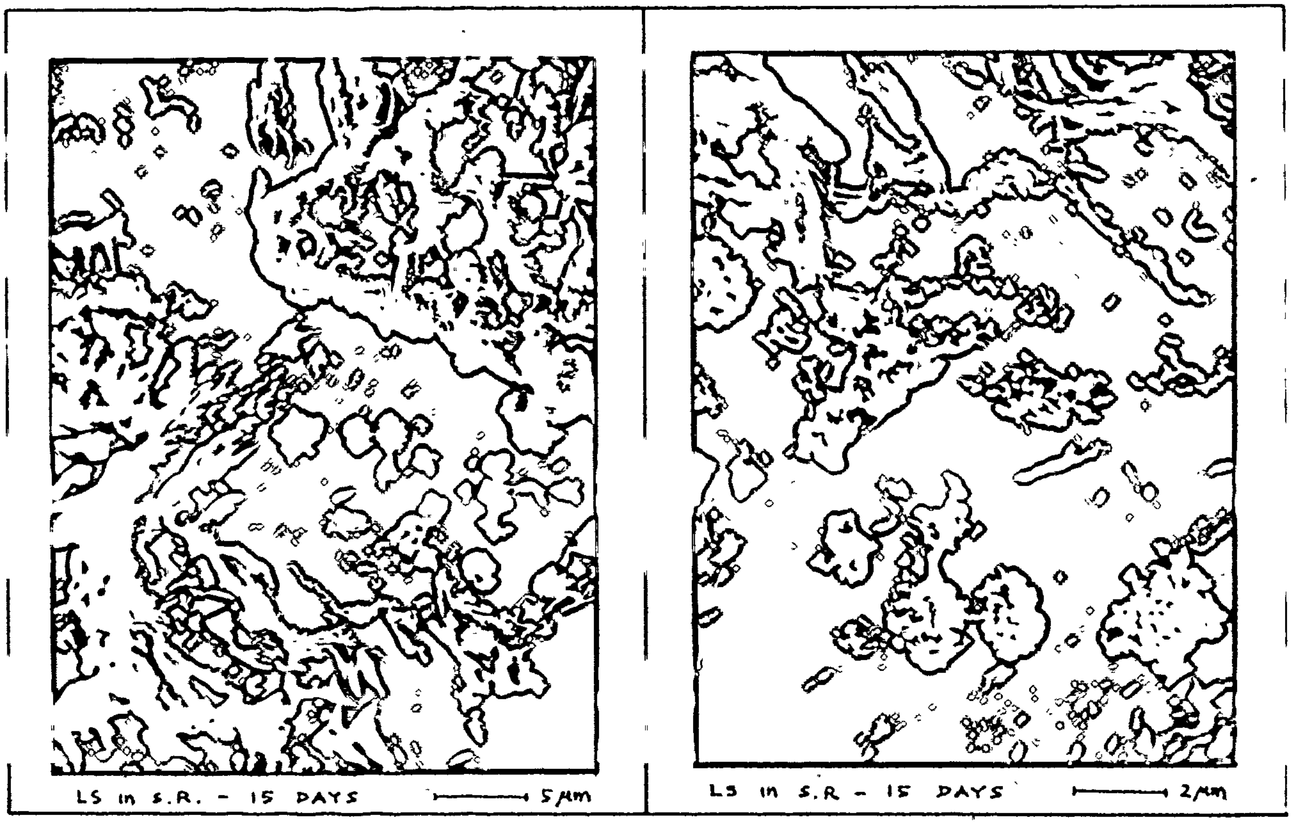


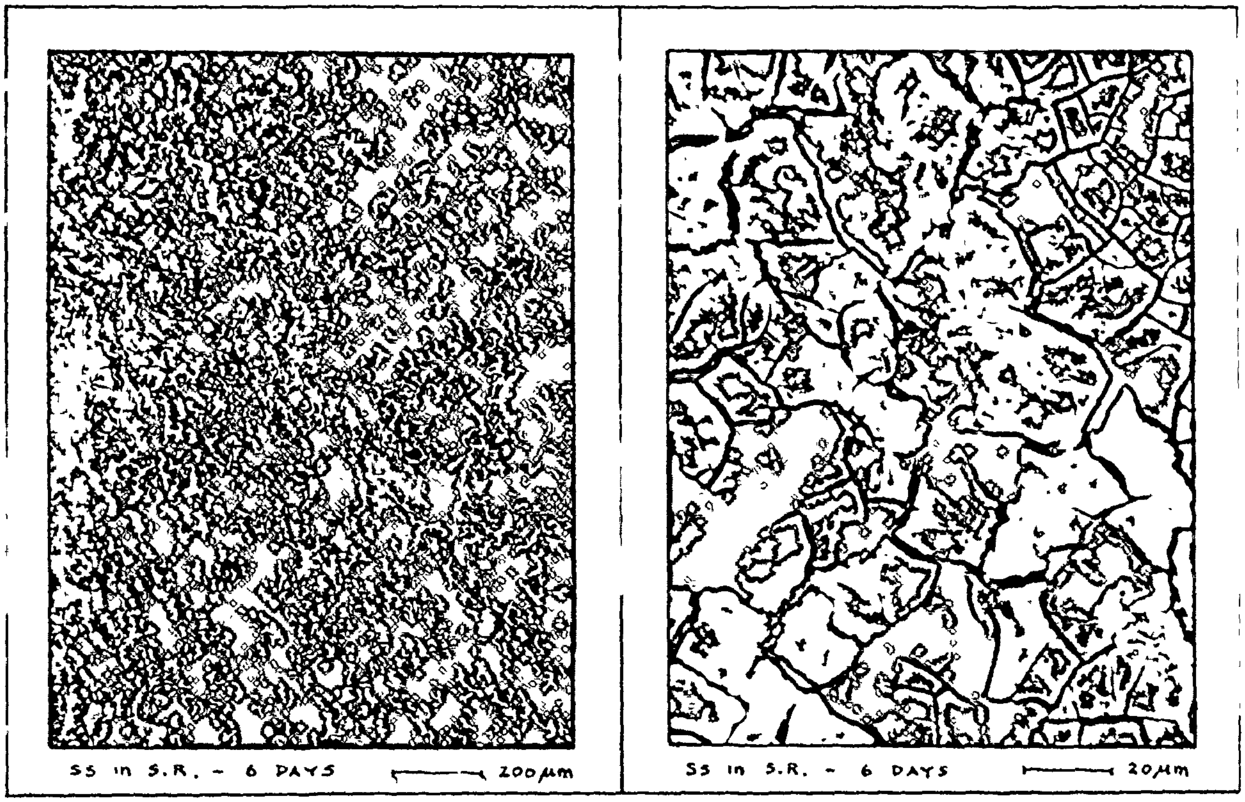


a. X250 b. X560

Figure 34: Limestone in Synthetic Rain: 15 Days

c. X2500 d. X6250

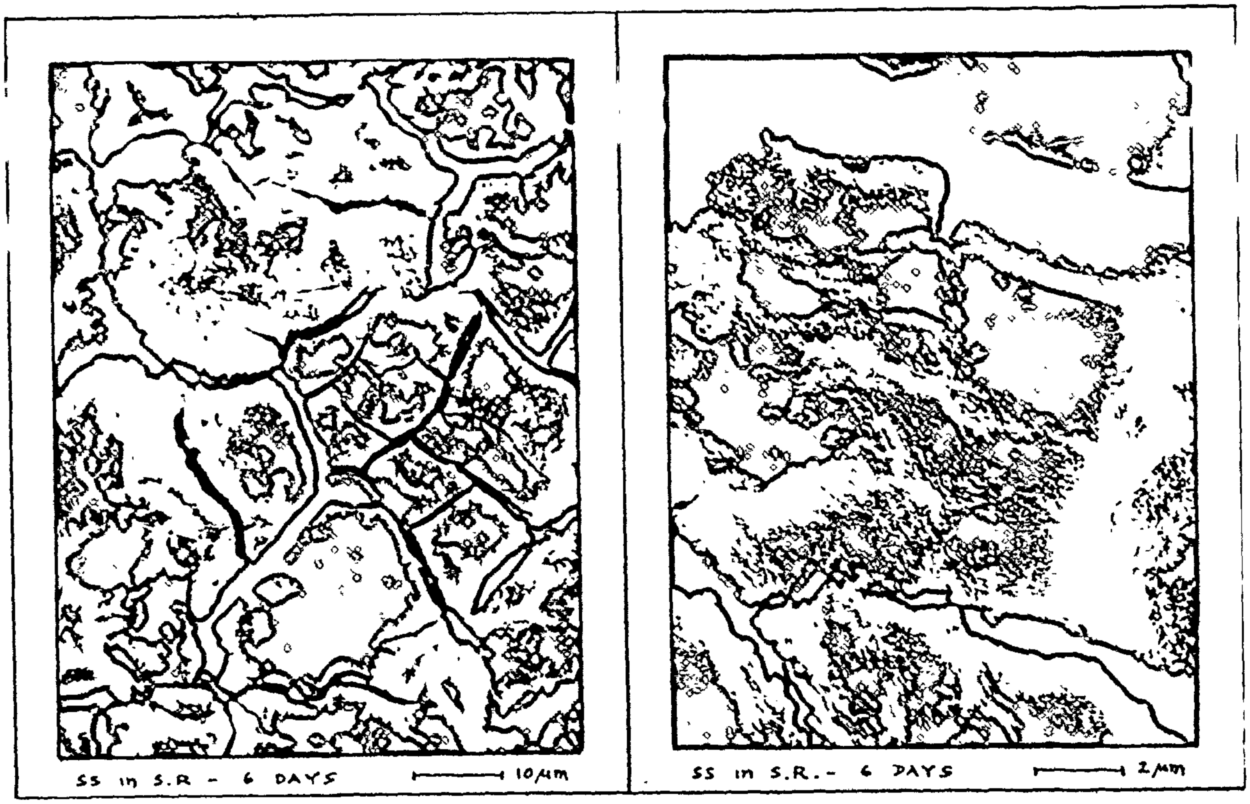


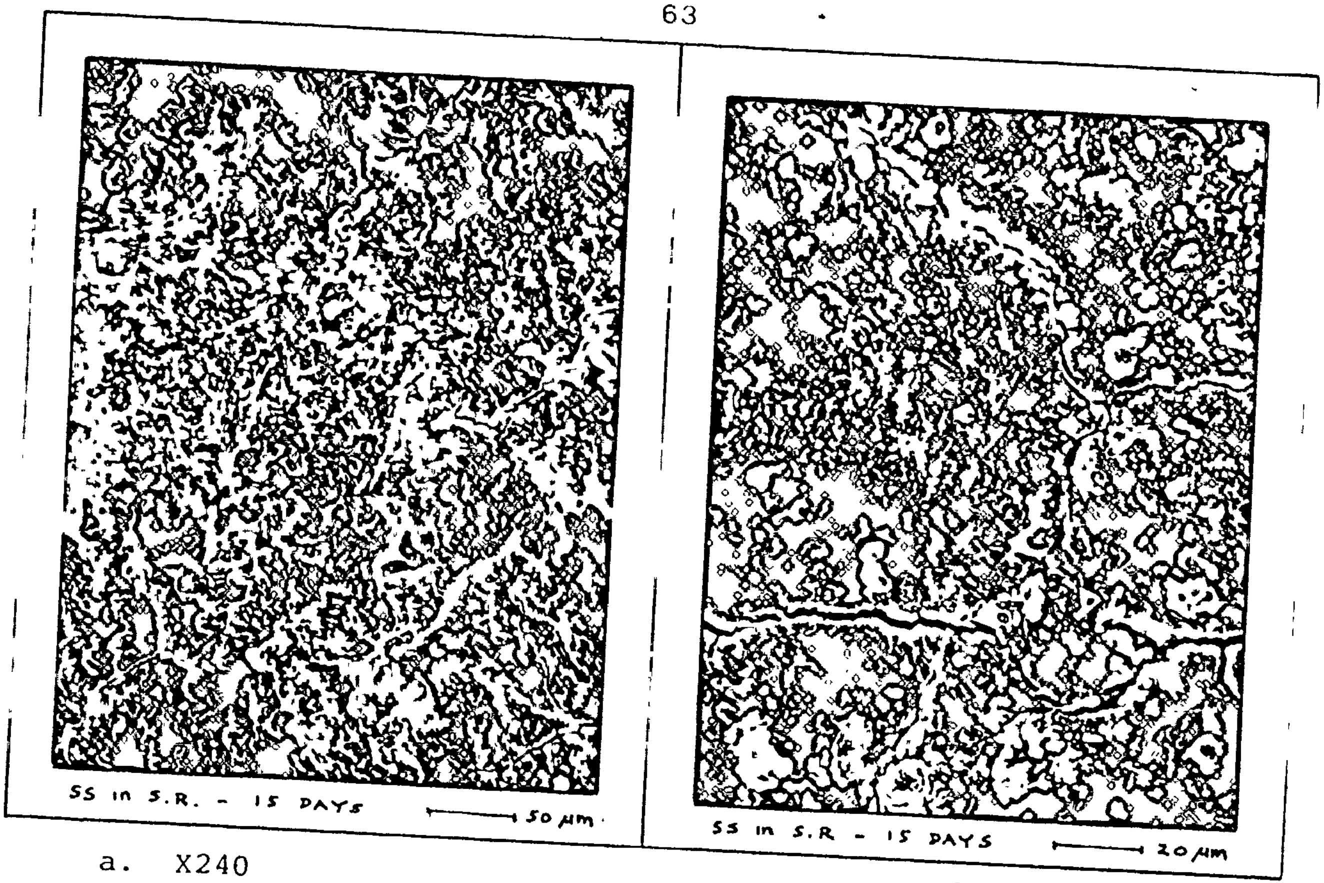


a. X62 b. X620

Figure 35. Steel Slag in Synthetic Rain: 6 Days

c. X1230 d. X6250





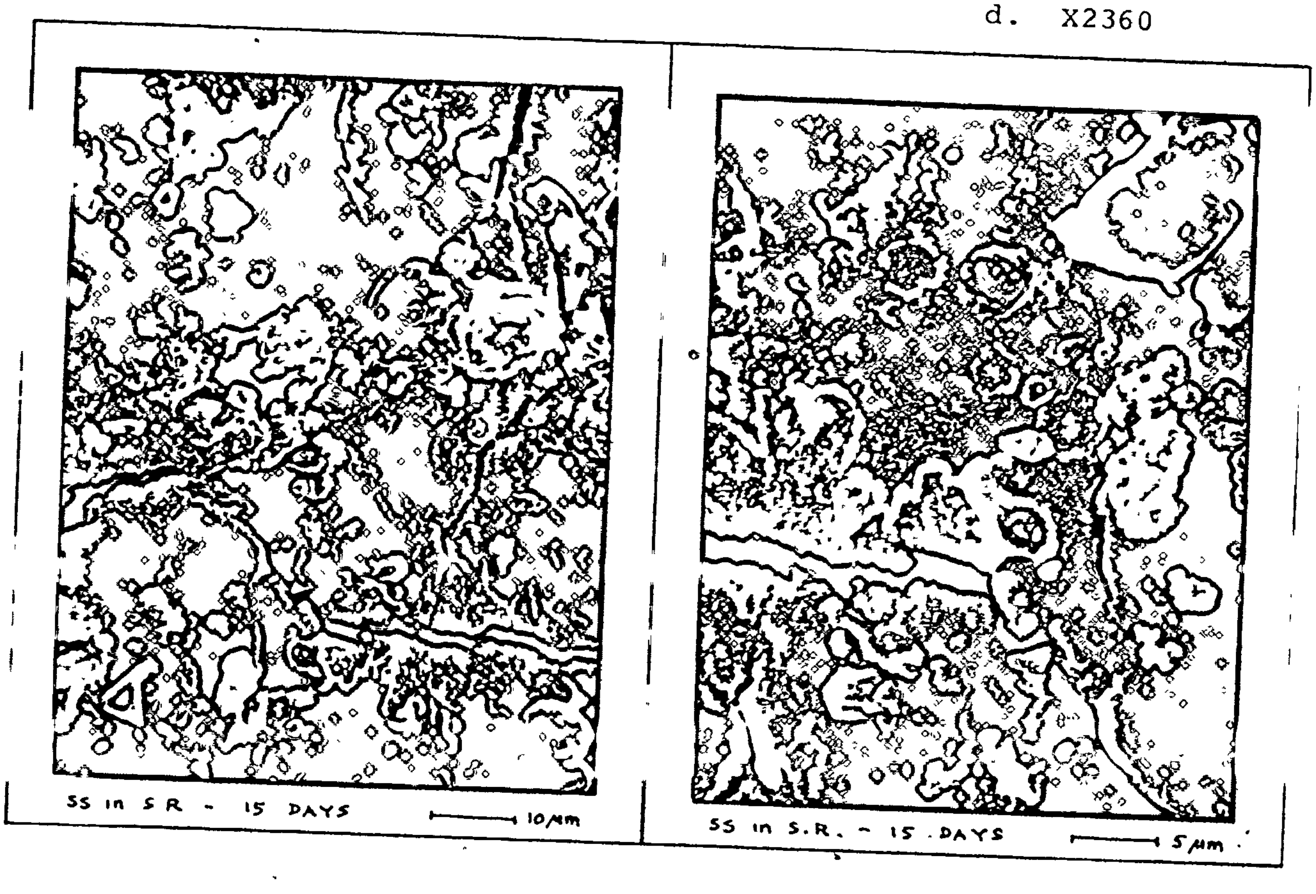
a. X240

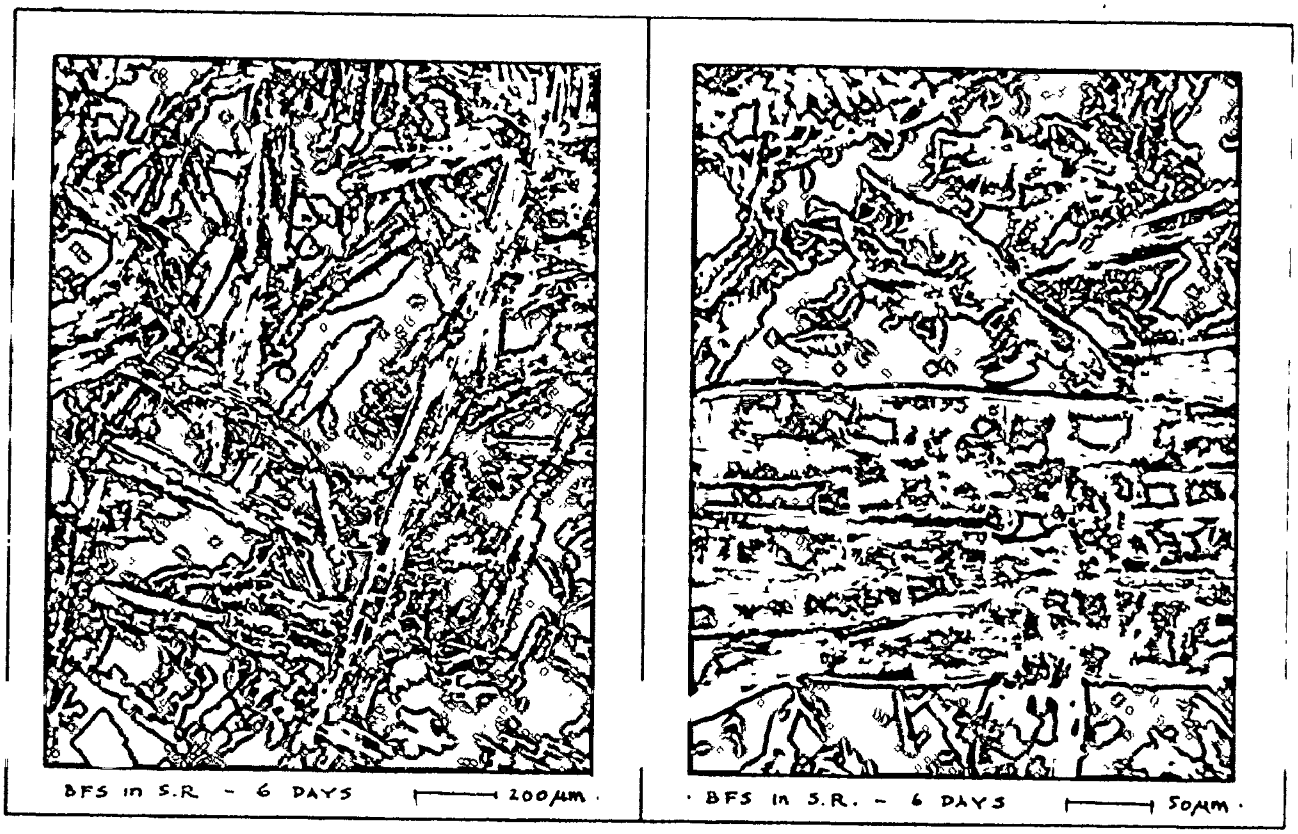
Figure 36. Steel Slag in Synthetic Rain: 15 Days

b. X580

c. X1160

d. X2360

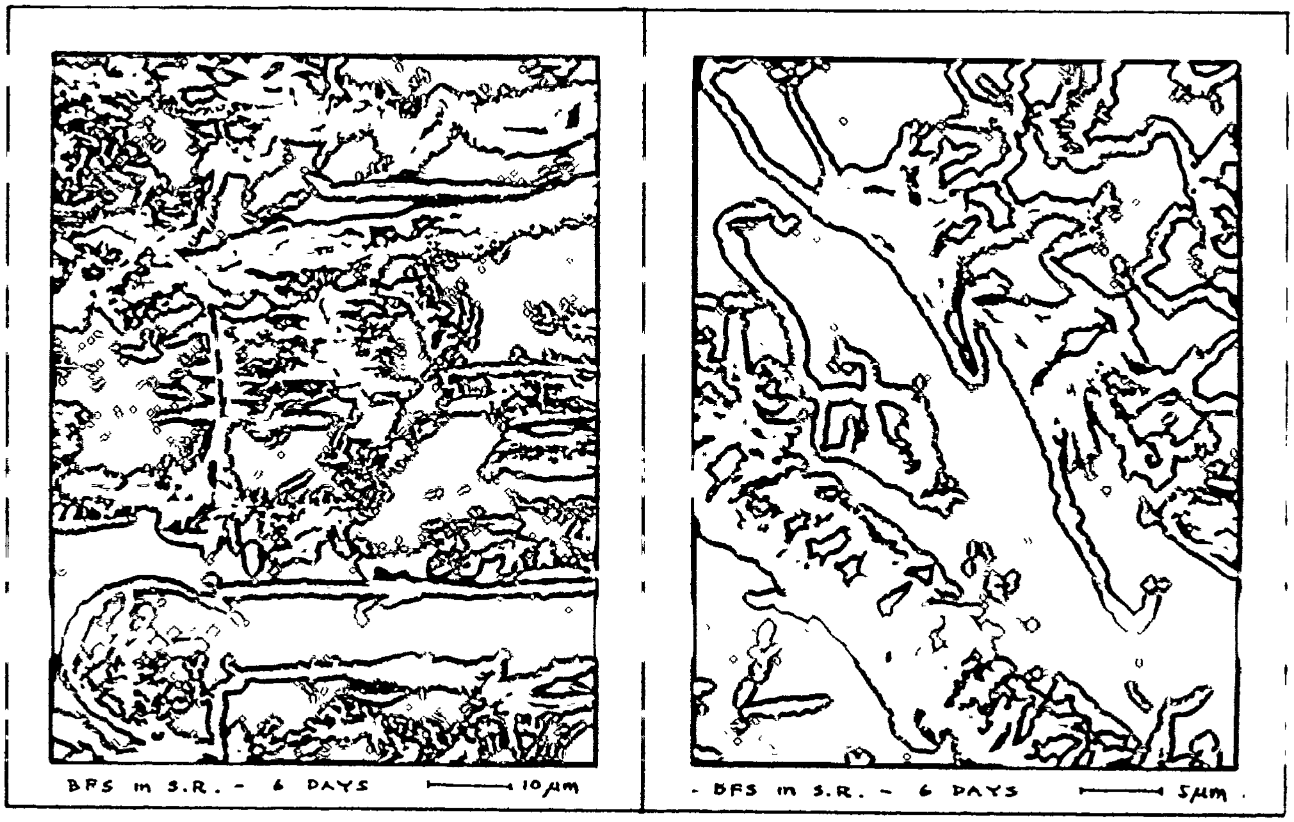


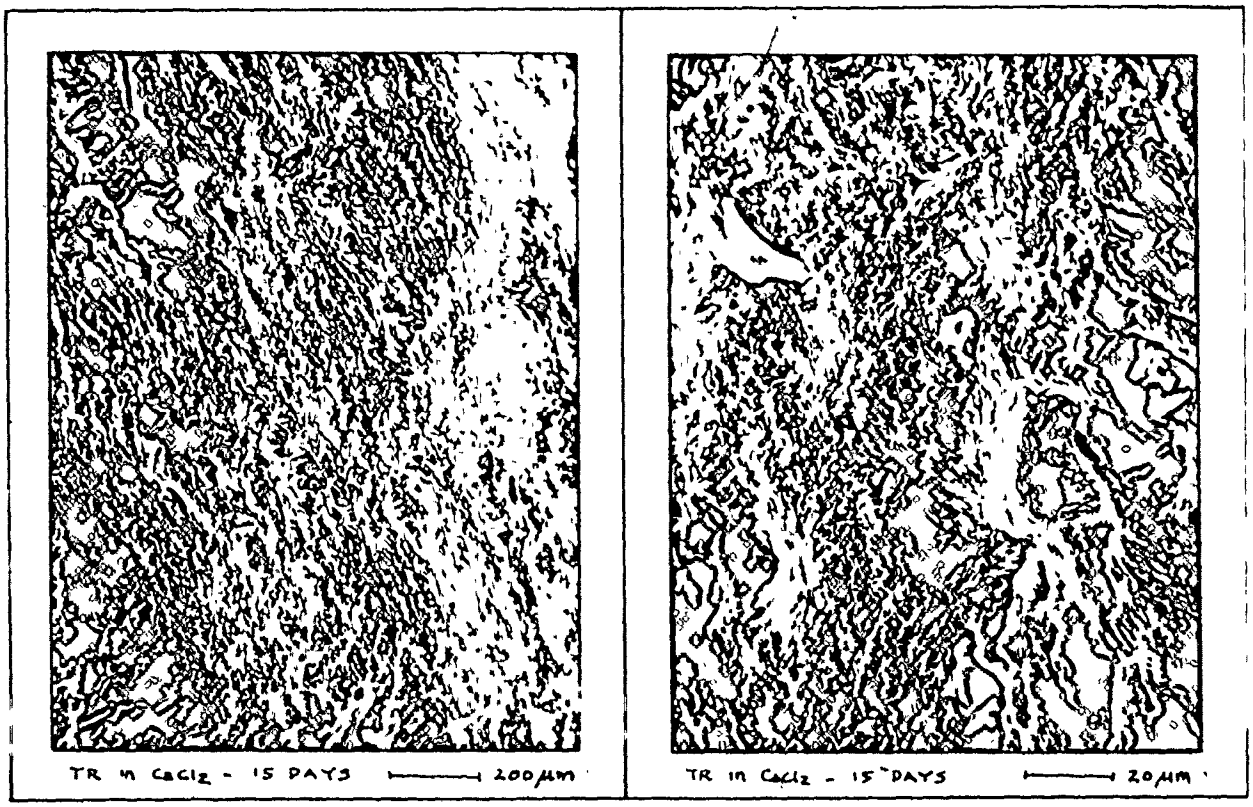


a. X55 b. X232

Figure 37. Blast Furnace Slag in Synthetic Rain: 6 Days

c. X1110 d. X2220

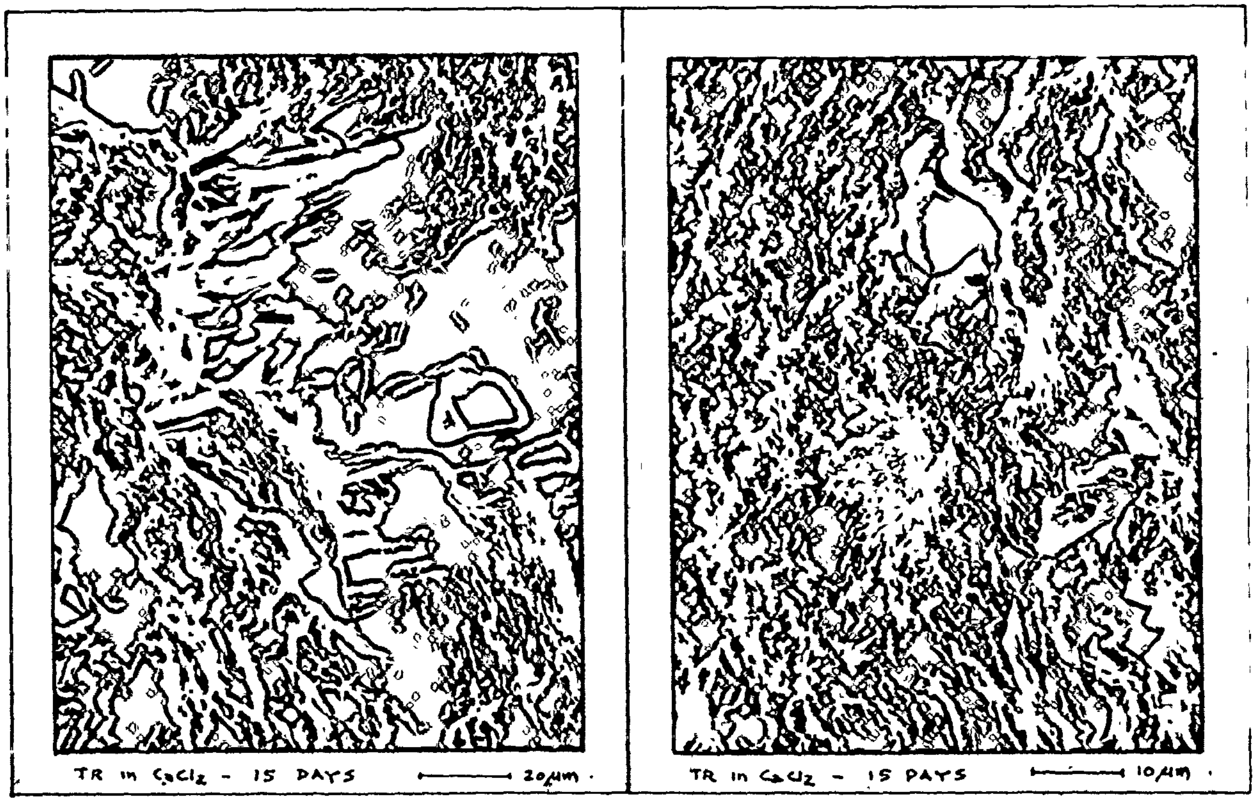


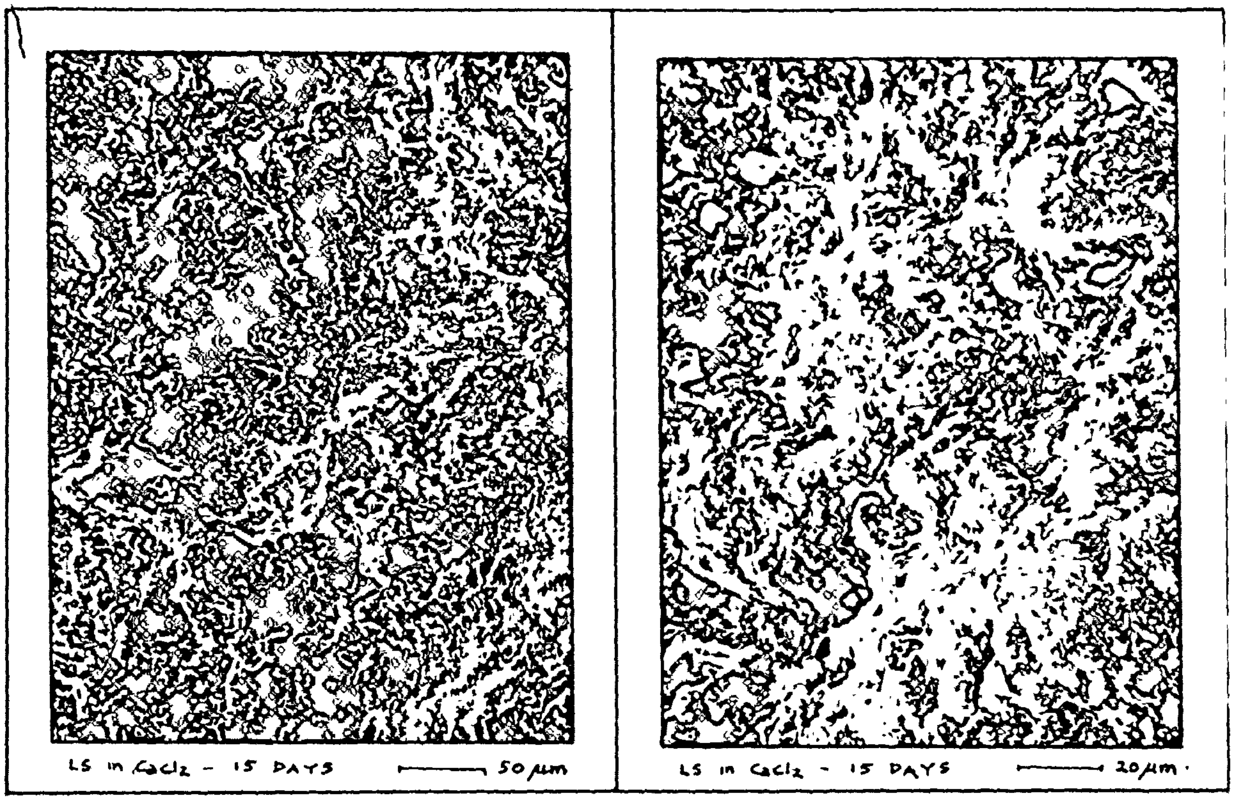


a. X63 b. X630

Figure 38. Traprock in $CaCl_2$ Solution: 15 Days

c. X630 d. X1260





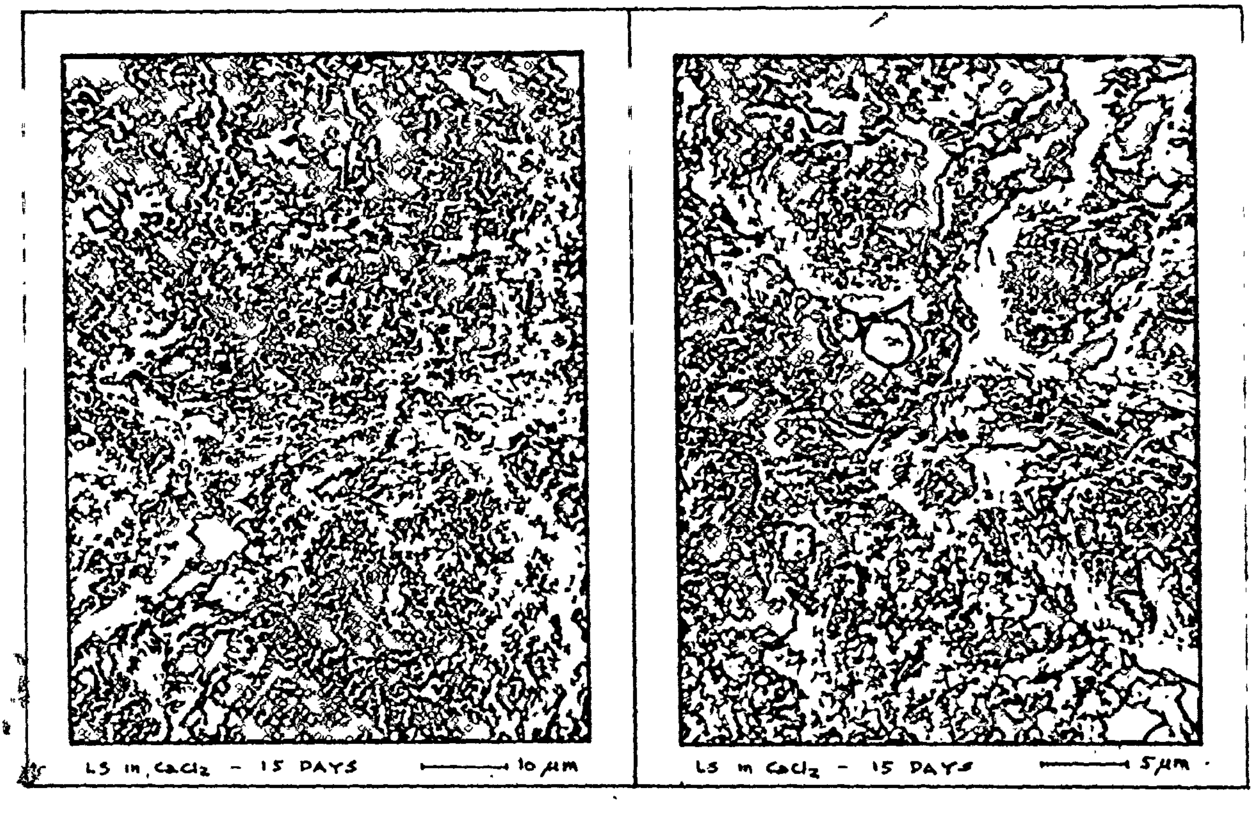
a. X240

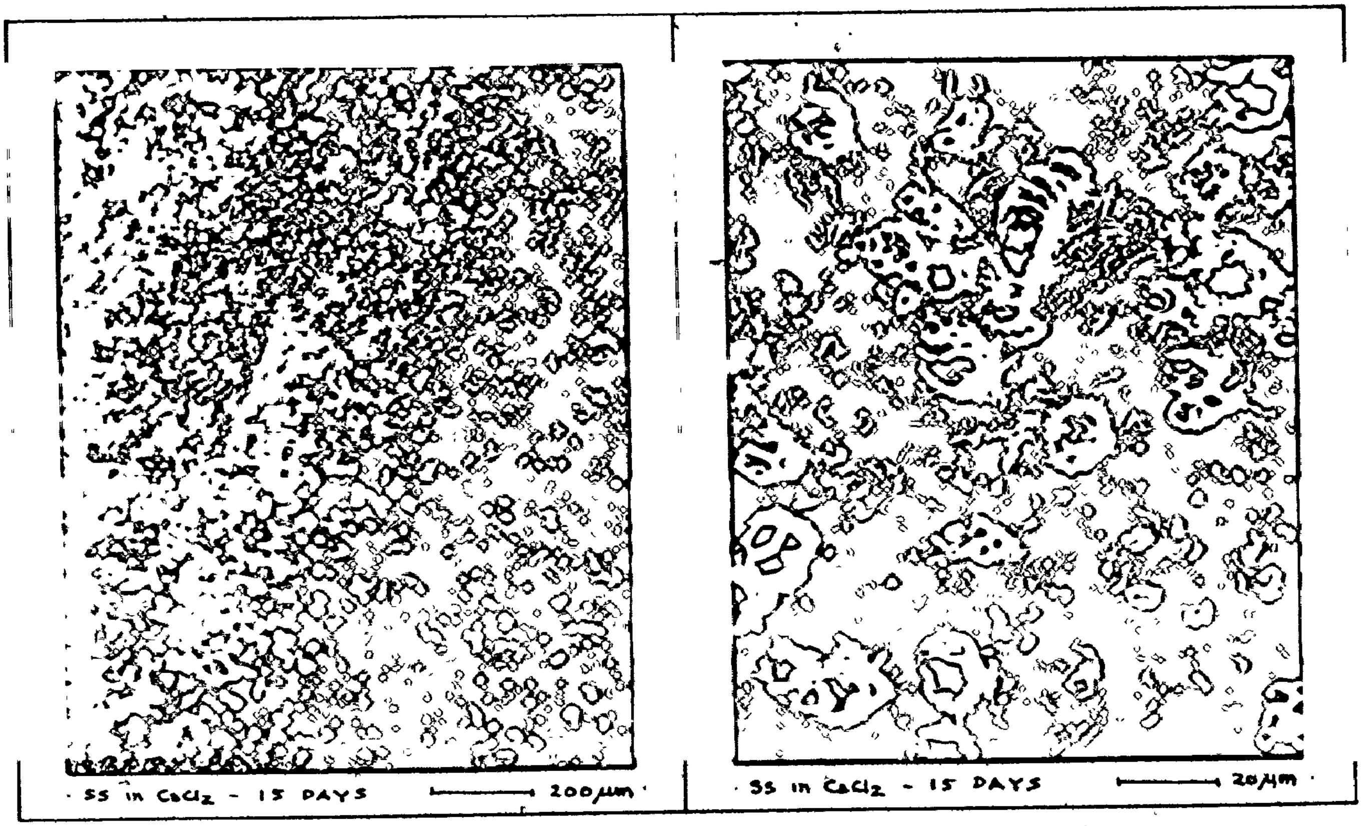
b. X600

Figure 39. Limestone in $CaCl_2$ Solution: 15 Days

c. X1200

d. X2400





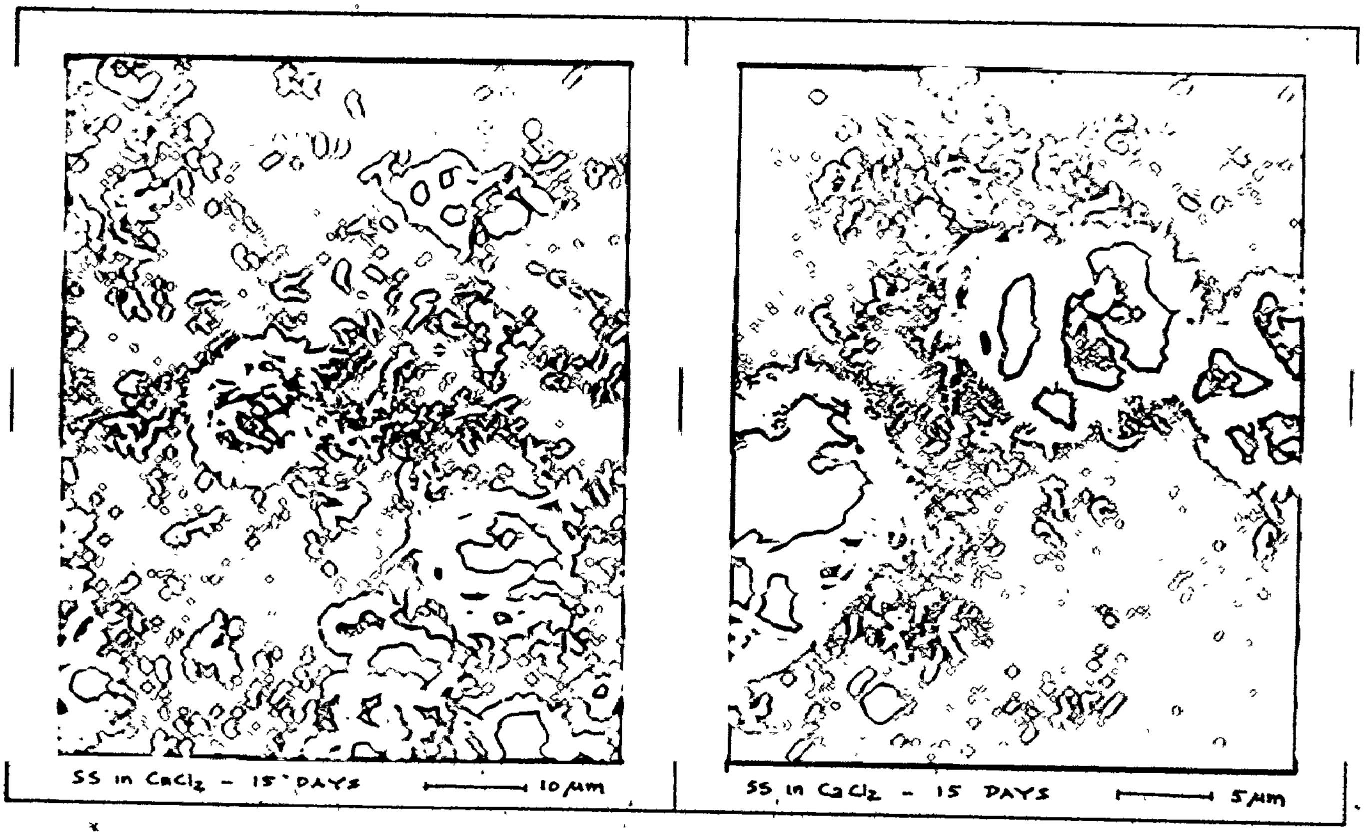
a. X64

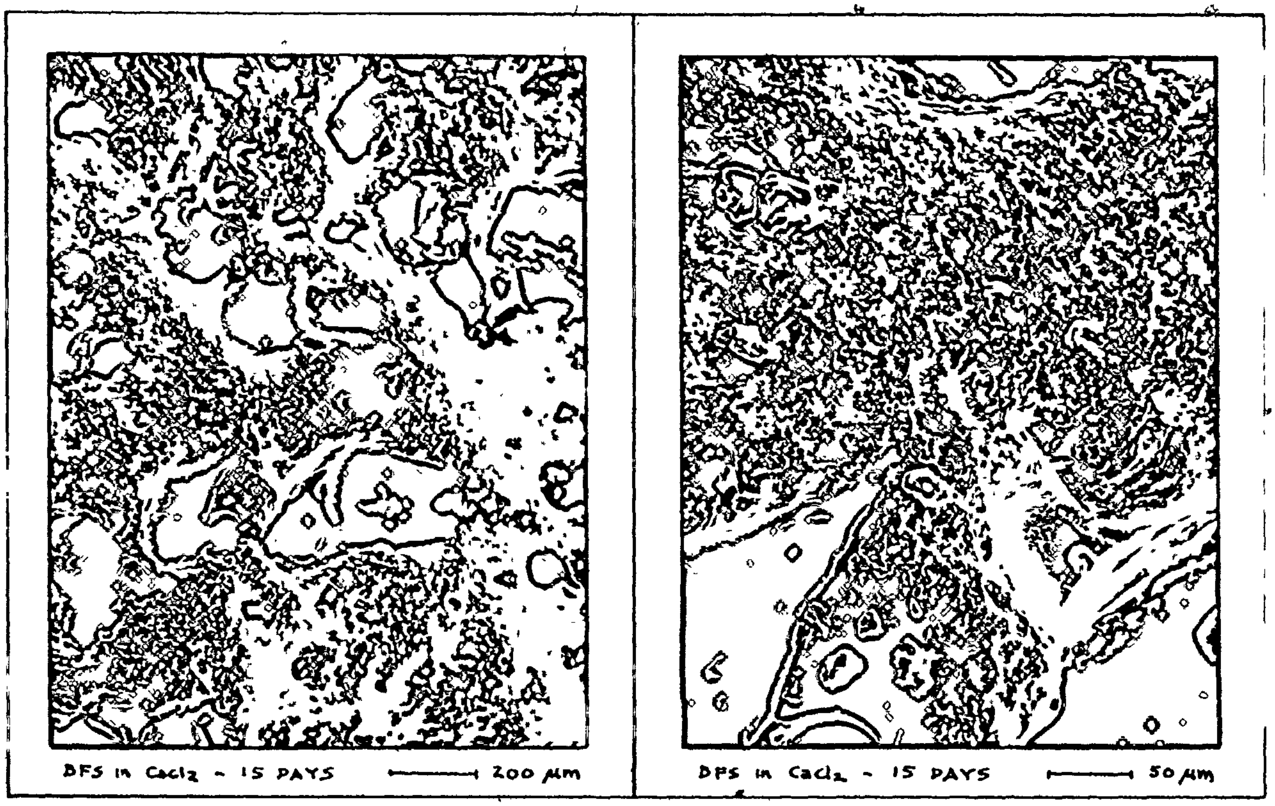
b. X650

Figure 40. Steel Slag in $CaCl_2$ Solution: 15 Days

c. X1300

d. X2500

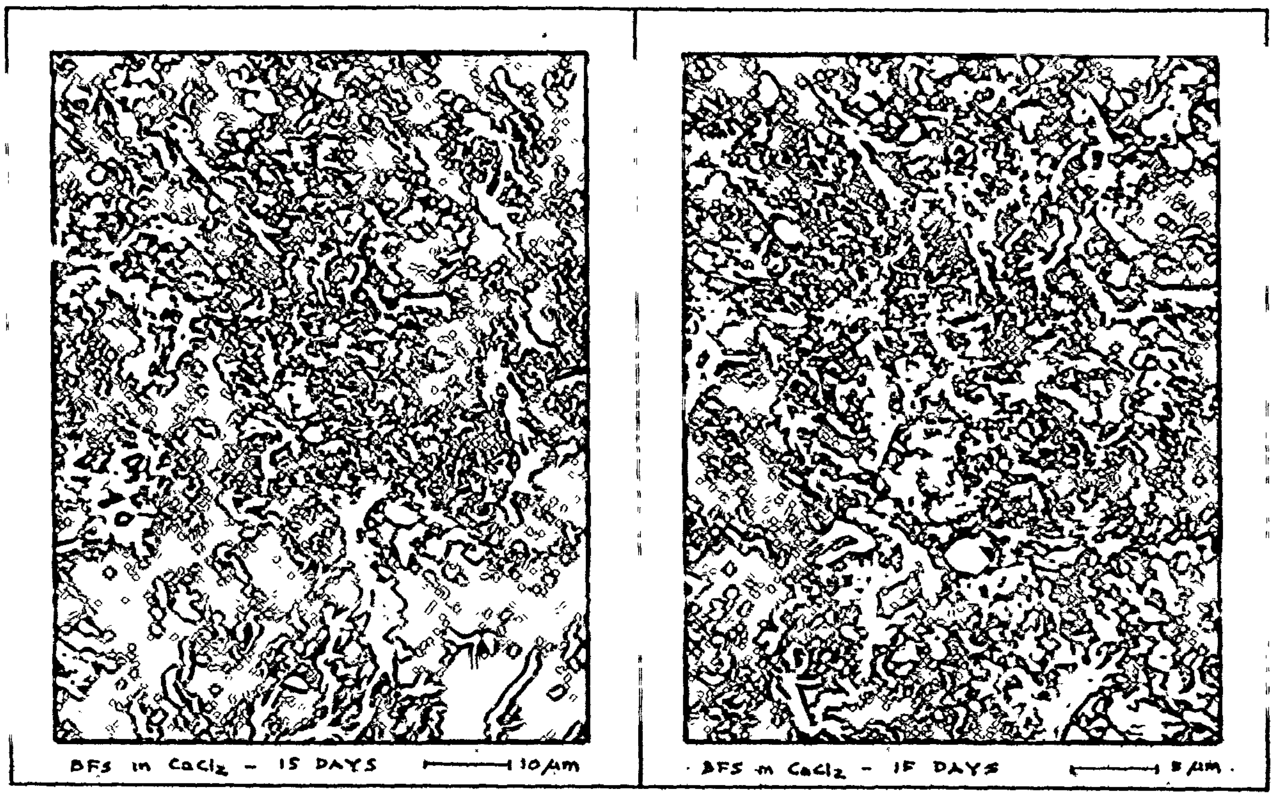




a. X59 b. X232

Figure 41. Blast Furnace Slag in $CaCl_2$ Solution: 15 Days

c. X1160 d. X2330



The visual observation from these micrographs, as well as the results from the x-ray diffraction analysis are described in the following sections.

3.6.4 WEATHERING PROCESS IN DISTILLED WATER

Typical photomicrographs for the aggregates subjected to simulated weathering in distilled water are given in Figures 19 to 26. For each aggregate, observations were completed after 6 and 15 days in solution. The results were as follows:

1. Traprock

   As shown in Figures 19 and 20, there was not much weathering after 6 days in distilled water. However, after 15 days, some contaminants and/or crystals developed on the surface of the traprock.

2. Limestone

   As shown in Figures 21 and 22 for limestone in distilled water, crystallization and/or surface contamination did not occur. However, both Figures show that the surface texture after weathering was much rougher than in the initial polished condition. It is believed that under this weathering condition, calcium (which is the main component of limestone) dissolved into the water and hence results in a rough, leached surface.

3. Dofasco Steel Slag

As shown in Figures 23 and 24, Dofasco steel slag in distilled water showed a similar behaviour to traprock. After 6 days, crystals formed on the surface. However, Figure 23 still shows a smooth surface with many "depressed" areas and secondary microtexture features. After 15 days in distilled water, the crystals were more evident.

4. Blast Furnace Slag

Typical photomicrographs of blast furnace slag after the weathering process in distilled water are given in Figures 25 and 26. The blast furnace slag surface did not show any significant changes after 6 days in distilled water. However, as shown in Figure 26 after 15 days, numerous crystals had formed on the surface.

3.6.5 WEATHERING PROCESS IN RAINFALL WATER

Typical photomicrographs of the aggregates after they were subjected to weathering in rainfall water are given in Figures 27 to 30. Due to the small surface changes observed, photomicrographs were only made after the aggregates had been in the solution for 15 days.

Generally, the weathering process which occurs in rainfall water is rather similar to the weathering process in distilled water, described in previous sections. This is due to the fact that the rainfall water collected was not polluted as indicated by chemical analysis given in Appendix I.

Generally, the microtexture of these aggregates, except for the blast furnace slag, were not greatly influenced by the rainfall water. For blast furnace slag, as shown in Figure 30, some crystals or surface contaminants can be seen at above X1000 and X2500 magnifications.

3.6.6 WEATHERING PROCESS IN SYNTHETIC RAIN

Typical photomicrographs of the aggregates that were subjected to simulated weathering in synthetic rain are given in Figures 31 to 37. Observations for these aggregates were as follows:

1. Traprock

   Figures 31 and 32 show typical photomicrographs for the traprock after weathering in synthetic rain. Crystals and surface contaminants could be detected after the traprock was submerged for 6 and 15 days in synthetic rain.

2. Limestone

As shown in Figures 33 and 34, the weathering effect of synthetic rain on the limestone surface texture could be clearly seen. Both Figures 33 and 34 show that the microtexture of the limestone was changed very drastically by the weathering.

3. Dofasco Steel Slag

Figure 35 shows the surface texture of the steel slag after 6 days in synthetic rain. Microcracks developed in the surface of the steel slag, that have also been described by others (12, 13). In their study, it was indicated that these cracks developed due to the calcium and the iron from the CaO/FeO and calcium aluminoferrite dissolving into the water.

In addition to these microcracks, Figure 36 also shows that some crystals and/or surface contamination developed with the steel slag after 15 days in synthetic rain.

4. Blast Furnace Slag

Photomicrographs of the blast furnace slag after 6 days in synthetic rain are given in Figure 37. They show that numerous cracks and cavities also developed in blast furnace slag, although it is not as extensive as found on steel slag. The photomicrographs at about X50 and X250 magnifications show some elongated patterns. These patterns may or may not have occured prior to weathering. Due to the ununiformity of blast furnace slag, the study of this aggregate in the SEM shows considerable variation of results, depending on individual particle chosen for examination.

3.6.7 WEATHERING PROCESS IN $CaCl_2$ SOLUTION

The observations of the weathering process in a $CaCl_2$ solution are shown in Figures 38 to 41. Similar to the weathering process in rainfall water, limited chemical actions occurred during the 15-day weathering period. As shown in Figures 38 and 41, some contaminants and/or crystal formed on the surface of the traprock and blast furnace slag.

3.6.8 X-RAY DIFFRACTION (XRD) ANALYSES ON THE AGGREGATE SURFACES

In this chapter, the second part of the weathering study involved the examination of the crystals and/or surface contaminants which developed on the surface of the aggregates after they were subjected to the weathering processes. Examinations were also completed on the surface of the aggregates to obtain their surface characteristics. The results for the x-ray diffraction (XRD) examinations are given in Appendix D, and can be summarized as follows:

1. Traprock

Surface characteristics:	Fe, Si, Ca, Al and trace of other elements such as Mg, Cl
Contaminants/crystals:	Fe, Si, Ca, Al and some Mg, Cl or Mn.

Traprock which is a basaltic rock, contains elements such as Al, Ca, Fe, Mn and Mg, as shown by the surface characteristics. The contaminants/crystals formed have the same composition, which indicate that this aggregate leaches during the weathering process. The small amount of these contaminants/crystals formed is an indication that the traprock is stable and influenced little by the presence of water, or chemicals from rainfall, synthetic rain or $CaCl_2$ solution.

2. Limestone

Surface characteristics: mainly Ca, Mg.
Very small amounts of Fe and Al detected, which may come from the detecting tube of the apparatus.
Contaminants/crystals: Mg, Ca, and some Si.

Generally, the surface contaminants/crystals formed were MgO, CaO or $CaCO_3$. These are "soft" crystals which are easily abraded or polished away.

This is probably one reason why limestone is heavily polished by traffic; although crystal rejuvenation, as shown on previous sections is quite high, especially for the case of limestone in synthetic rain.

3. Dofasco Steel Slag

Surface characteristics:	Fe, Ca, Mn, Al, Si and some Mg
Contaminants/crystals :	mainly (large amount) Ca and Fe, with smaller amount of Al, Mn, Mg and Si.

It is known that some components of steel slag are FeO/CaO, Rankinite (3 $CaO.2SiO_2$) and Merwinite (3 $CaO.MgO.2SiO_2$). The crystals that formed contained a large amount of Ca and Fe, which dissolved from the surface as shown by other studies (12, 13). Microcracks which developed on the surface were primarily caused by the dissolving of Ca and Fe into the solution. Crystallization also developed on the surface of the aggregate. The steel slag surface is very hard, as observed from its low AAV. Therefore, the introduction of "microcracks" will enhance its microtexture for quite a while. Unlike crystal development of the surface, these cracks are very deep and they act as an important microtexture between the tires and the surface of the aggregate.

4. Blast Furnace Slag

Surface characteristics: Al, Si, Ca, some Fe and Mg

Contaminants/crystals: Al, Si, Ca and some Fe.

Unlike steel slag, there were less microcracks developed in the surface of blast furnace slag after weathering. Some components of blast furnace slag are CaO, MgO, or combinations of Ca, Mg, Al and Si, such as Akermanite ($2\ CaO.MgO.2SiO_2$) or Gehlenite ($2\ CaO.Al_2O_3.SiO_2$) as described by other studies (14, 15). Crystals which may have formed are combinations of Al, Si, Ca and O, such as Gehlenite, CaO, MgO or Al_2O_3. The CaO and MgO are very soft and cannot resist polishing for long.

3.6.9 SUMMARY

The observation of weathering effects of aggregate surfaces using the SEM and XRD analyses were found to be very useful in studying the process, the chemicals and the surface texture development involved in weathering. Generally, it was found that the weathering process is rather "complex" in terms of conditions at the road surface. The following factors contribute to the complexity of the weathering process:

a. time;

b. chemical composition of the aggregate surface (chemical characteristics);

c. chemical composition of the solution;

d. mechanism of chemical reactions involved in the weathering process;

e. composition and physical characteristics of contaminants/ crystals that formed; and

f. chemical and physical stability of contaminants/ crystals that formed.

Time and the chemical composition of both the aggregate and the solution effect the rate at which the weathering can progress, as well as the possibility of reactions to occur. In case of traprock, the aggregate composed of chemically stable components so that reactions with solutions appear to be minimal.

One of the most important findings is the mechanism of chemical reactions involved in the weathering process. This hypotheses can be used to explain the skid resistance performance of the aggregate, especially any repolishing after weathering occurs (i.e., interaction of weathering texture rejuvenation and polishing removal of texture).

Generally, there are two processes of chemical action:

1. The formation of crystals and/or surface contaminants. This occurs due to the interaction and reaction of chemical components upon contact with each other. Crystals which form on the surface enhance the micro-texture condition, as they make the surface rougher. This mechanism will be termed a "positive" rejuvenating process.
2. In contrast to this positive rejuvenating process, a "negative" rejuvenating process is caused by the development of deep microcracks, which also enhances the microtexture of the surface. Negative rejuvenating is caused by the leaching of the aggregate components by weathering. This is a mechanism which occurs during the weathering of steel slag. In this case, little crystal structure formed on the surface, so that polishing or wear only attacts the depths of these cracks. The surface of the steel slag is generally hard, therefore, the negative rejuvenating process is more effective since it can stand repolishing without lowering its PSV.

With regards to the positive and negative rejuvenating mechanism, some findings can be summarized as follows:

1. Traprock

   No negative rejuvenating occurs, and positive rejuventating is very limited.

2. Limestone

   Very high positive rejuvenating occurs during weathering, especially for limestone in synthetic rain. However, due to soft crystals formed, the increase in PSV is temporary and easily polished away by traffic. The deep microcracks provide a good microtexture surface.

3. Steel slag

   Both positive and negative rejuvenating occur. Primarily due to the negative rejuvenating process, steel slag is very resistant to re-polishing by traffic. The deep microcracks provide a good microtexture surface.

4. Blast furnace slag

   Mainly positive rejuvenating occurs, although limited negative rejuvenating might also occur. Due to the high abrasion characteristics of blast furnace slag, the increase in PSV by weathering may only be temporary.

It was also found that the chemical composition of the solution is very important to the weathering process. Generally, the presence of acid enhances the weathering process, whereas the presence of salts in the solution slows down the weathering process. Since most composition of aggregates are oxides (CaO, FeO, MgO, etc.) or hydroxides ($Ca(OH)_2$, $Mg(OH)_2$, etc.), the presence of alkaline solution does not greatly effect the weathering process. However, weathering process occurs very rapidly for aggregates which are submerged in synthetic rain which has a fairly high acidity (pH around 3.0); and occurs very slowly in rainfall water which is weakly acidic solution and contains some salts (carbonates, chlorides, etc.). The presence of salt in the solution (as in $CaCl_2$ solution) inhibits the weathering process.

4. STEREOMICROGRAPHS OF AGGREGATES TAKEN OUT OF HIGHWAY 401 TEST SECTIONS

4.1 CORE SAMPLES

As shown in the previous chapter, the use of photomicrographs for the evaluation of aggregate skid resistance performance has been found to be very useful. The effects of polishing, abrasion and simulated weathering on the aggregate surface texture can be examined by this method.

However, all of the results which were obtained in the previous chapter were essentially based on laboratory work. The processes of polishing, abrasion and weathering were simulated and they were treated separately. This does not represent the actual interacting processes at the road surface. In the real situation, polishing, abrasion and weathering occur and interact simultaneously. Furthermore, there are many other factors, particularly traffic action, which make the situation more complex.

To study the actual skid resistance performance of the aggregates, core samples were obtained from the Highway 401 Test Section (Toronto By-pass). Information regarding the test section is given in Appendix B (16). In order to determine if there was any seasonal weathering influence on the surface texture of the aggregates used, the core samples were taken during both the fall and spring seasons. The first core samples, consisting of cores taken from Test Section No. 1, 3, 7, 9 and 13 were obtained during the Fall of 1978. From these cores, a total of 22 selected aggregates were taken out of the cores and examined in the SEM.

The second set of samples, consisting of cores taken from the same test sections, were obtained during the Spring of 1979. From these cores, a total of 28 selected aggregates were examined in the SEM. Unfortunately, there were no test sections in which limestone was used as the coarse aggregate. Therefore, the study did not generate field information on skid resistance performance of limestone. The core sample information is summarized in Tables 1 and 2.

4.2 STEREOMICROGRAPHS

To obtain three dimensional pictures, each of the aggregates was photographed in pairs in the SEM. Each of these pictures had a slightly different orientation from its pair, so that stereomicrographs were obtained for

Table 1. Information for Cores Taken During the Fall of 1978

TEST SECTION NO.	CORE NO.	STUB NO.+	LANE / WHEEL TRACK @	AGGRE-GATE *
1	2	6	D/OWT	TR
	4	7	P/OWT	TR
	6	8	P/BWT	TR
	6-MC	9	P/BWT	TR
3	8	10	D/OWT	TR
	10	3-10	P/OWT	TR
	10-MC	3-10MC	P/OWT	TR
	12	12	P/BWT	TR
	12-MC	11	P/BWT	TR
7	14	7-14	D/OWT	SS
	14-MC	7-14MC	D/OWT	SS
	16	13	P/OWT	SS
	18	14	P/OWT	SS
	18-MC	15	P/OWT	SS
9	20	16	D/OWT	BFS
	22	17	P/OWT	BFS
	24	18	P/BWT	BFS
	24-MC	19	P/BWT	BFS
13	26	20	D/OWT	TR
	28	21	P/OWT	TR
	30	22	P/BWT	TR
	30-MC	23	P/BWT	TR

Notes:

+ MC : asphalt cleaned off aggregate

@ D : driving lane
P : passing lane
OWT : in wheel track
BWT : between wheel tracks

* TR : traprock
SS : Stelco steel slag
BFS : blast furnace slag

Table 2. Information for Cores Taken During the Spring of 1979

TEST SECTION NO.	CORE NO.	STUB NOS.	LANE/ © WHEEL TRACK	AGGREGATE *
1	1	1,2	P/BWT	TR
	2	3,4	P/OWT	TR
	3	5,6	D/OWT	TR
3	4	7,8	P/BWT	TR
	5	9,10	P/OWT	TR
	6	11,12	D/OWT	TR
7	7	13,14	P/BWT	SS
	8	15,16	P/OWT	SS
	9	17,18	D/OWT	SS
9	10	19,20	P/BWT	BFS
	11	21,22	P/OWT	BFS
	12	23,24	D/OWT	BFS
13	14	25,26	P/OWT	TR
	15	27,28	D/OWT	TR

Notes:

© D : driving lane
P : passing lane
OWT : in wheel track
BWT : between wheel tracks

* TR : traprock
SS : Stelco steel slag
BFS : blast furnace slag

examination using a stereoscope. Stereomicrographs are particularly useful, since they provide detailed information regarding the actual depth of the surface texture. With the stereoscope, one can readily see the high and low areas on the surface of the aggregates.

Typical stereomicrographs for traprock, Stelco steel slag and blast furnace slag obtained from the Highway 401 Test Sections are given in Figures 43 to 54. The coding and labelling system is given in Figure 42. For convenience, all micrographs are attached with the information on the top of them. This information consists of the position in the stereoscope, scale, magnification, direction of traffic, and the location where the aggregate was taken.

Each of these figures consists of two sets of stereomicrograph pairs: one set was taken during the fall of 1978, and the other set was taken during the spring of 1979. Both sets in each figure were taken at about the same magnification.

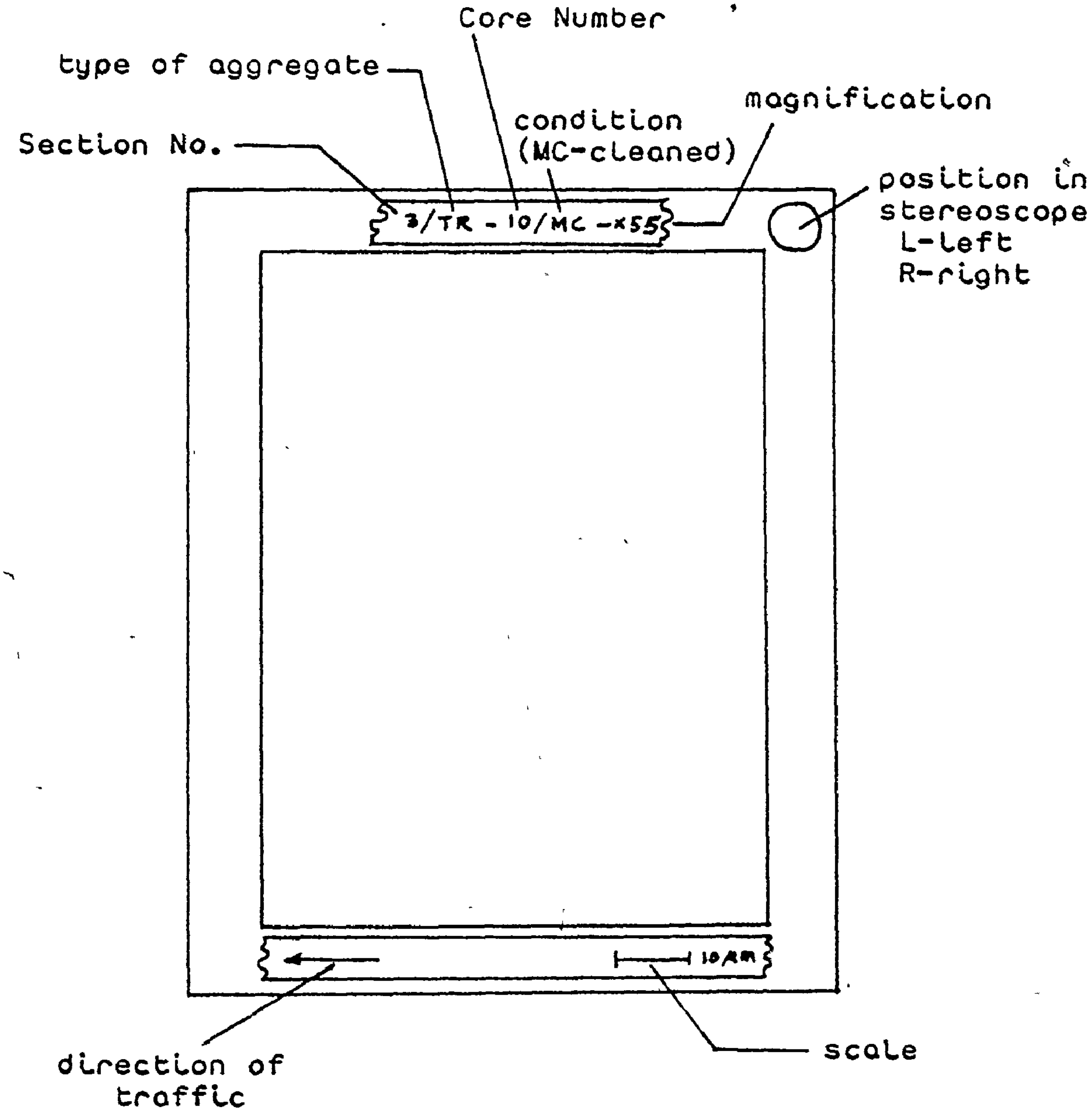


Figure 42. Coding and Labelling System

Typical stereomicrographs for the traprock are given in Figures 43 to 48. Figures 43 to 45 show the stereomicrographs for the traprock used in HL-1 asphaltic concrete mix, whereas the stereomicrographs for the traprock

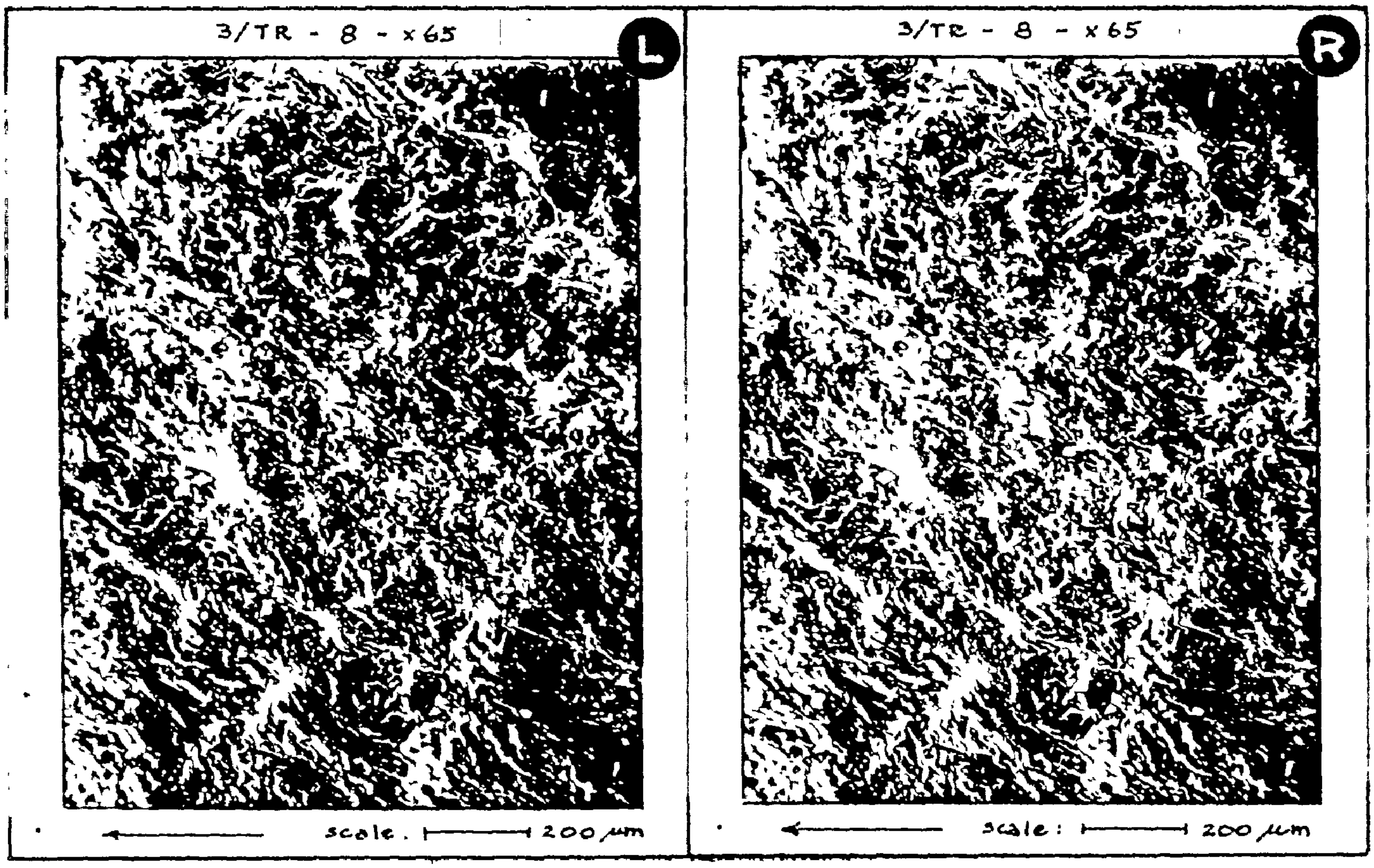
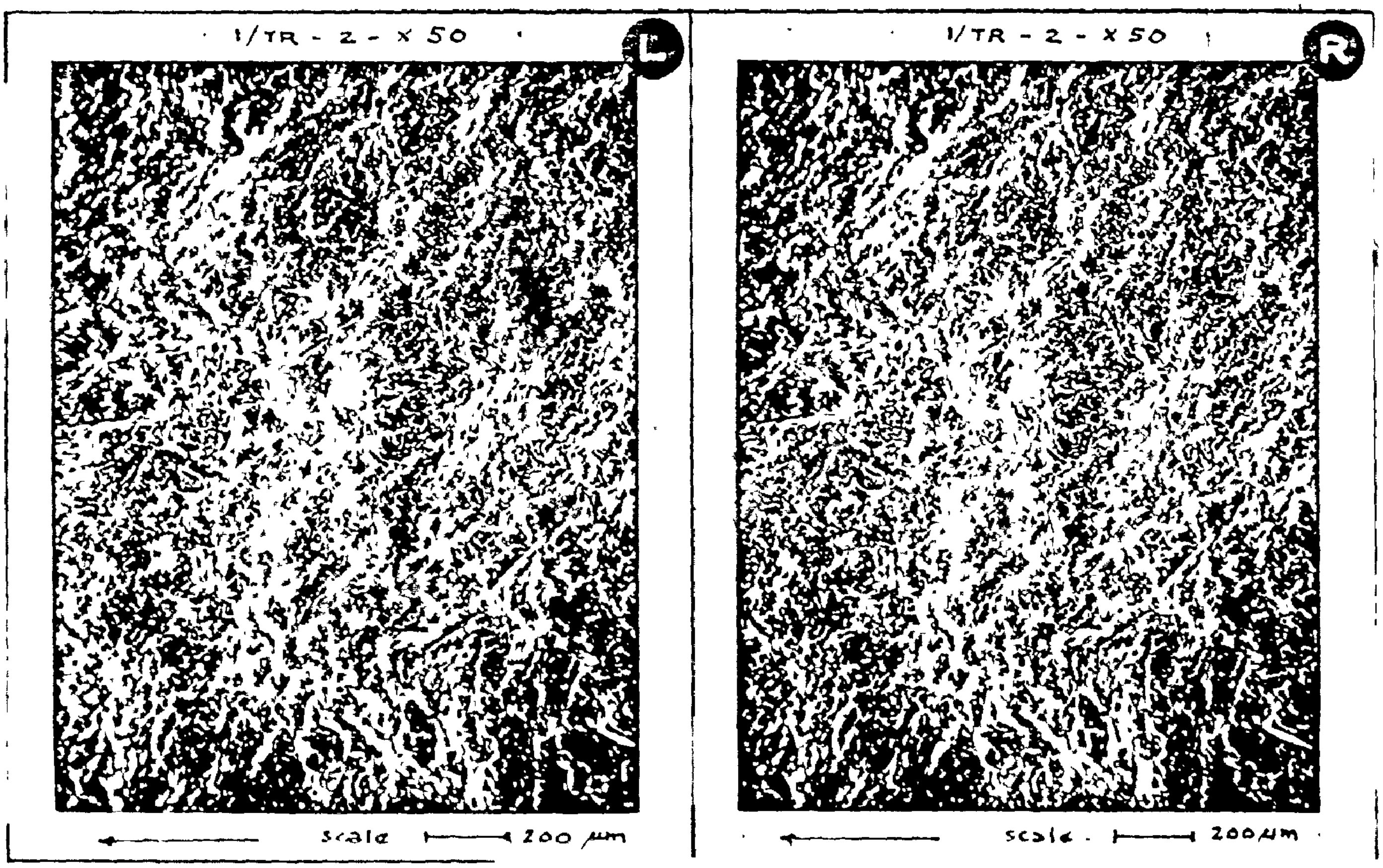


Figure 43. Typical Stereo-micrographs of Traprock (HL 1 Mix). Test Section : 3/TR

Pairs a. Fall 1978

Pairs b. Spring 1979



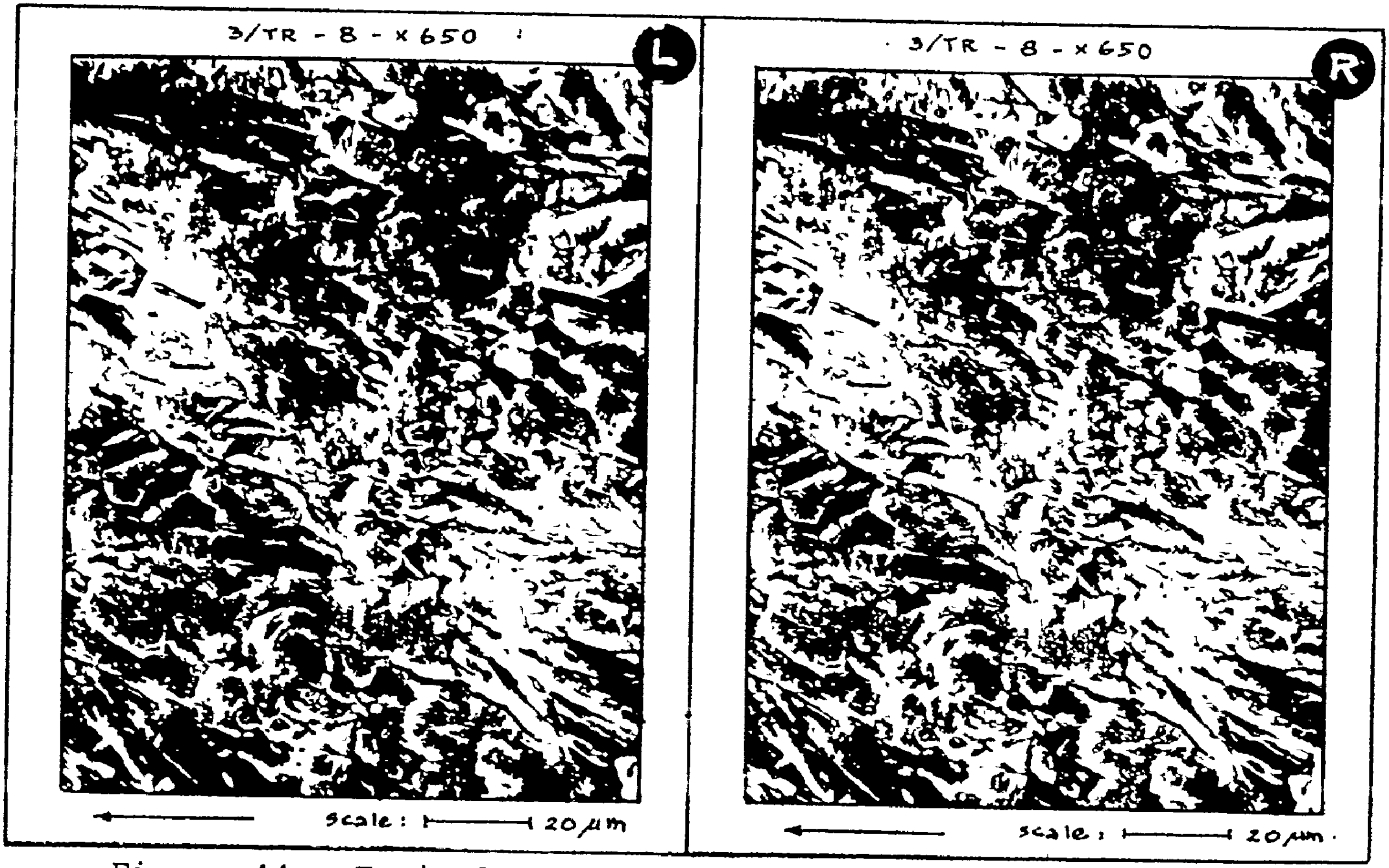
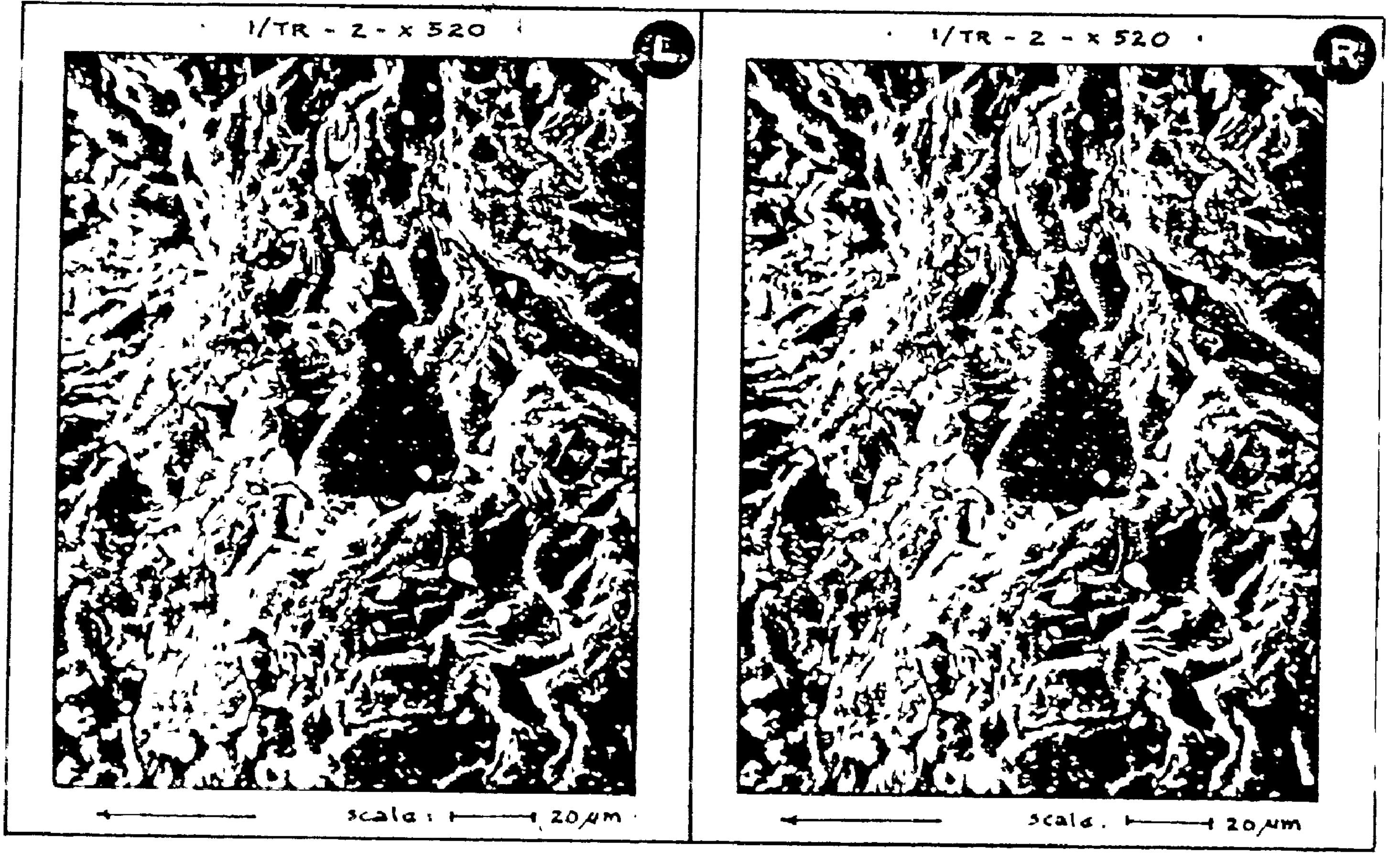


Figure 44. Typical Stereo-micrographs of Traprock (HL 1 Mix) Test Section : 3/TR

Pairs a. Fall 1978

Pairs b. Spring 1979



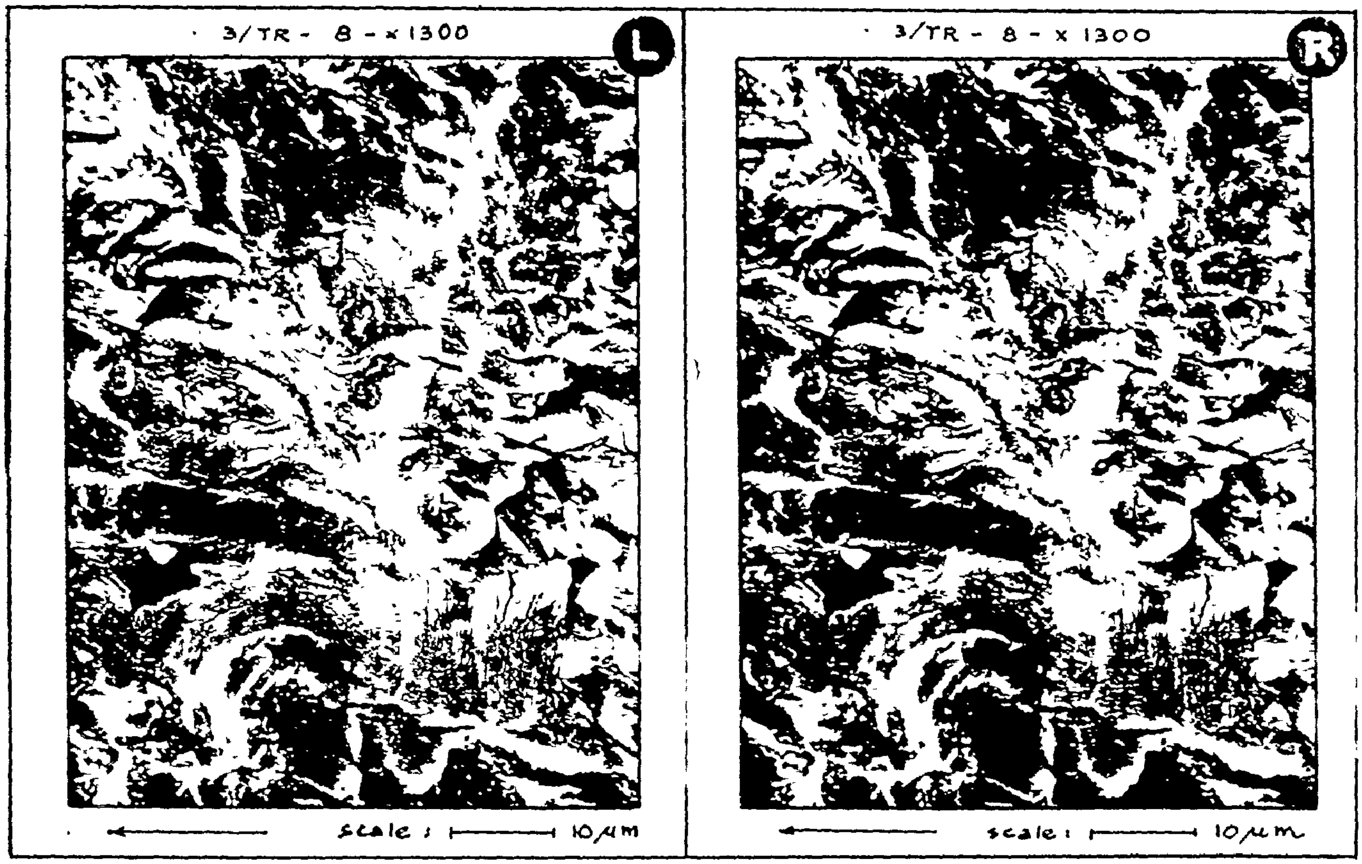
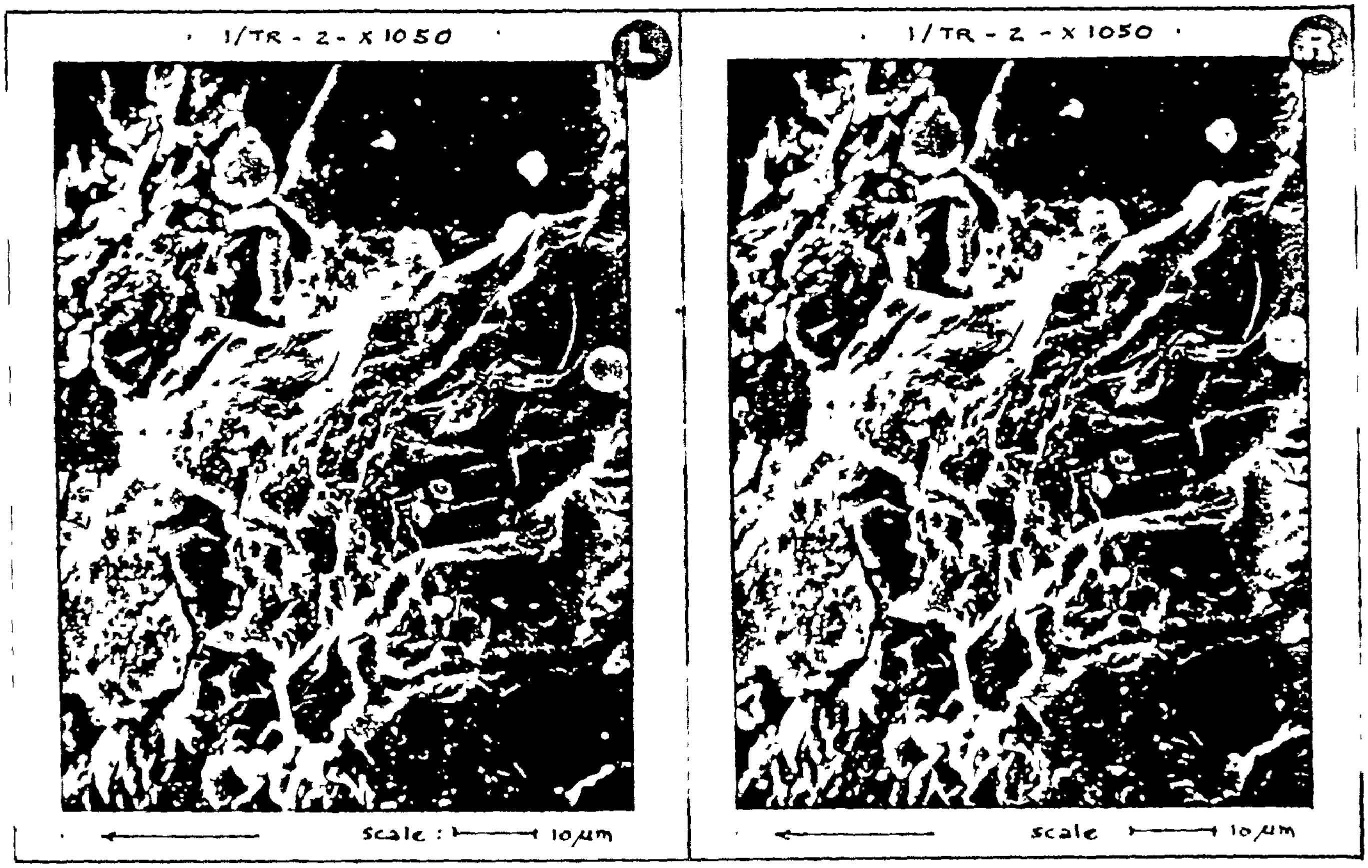


Figure 45. Typical Stereo-micrographs of Traprock (HL 1 Mix) Test Section : 3/TR

Pairs a. Fall 1978

Pairs b. Spring 1979



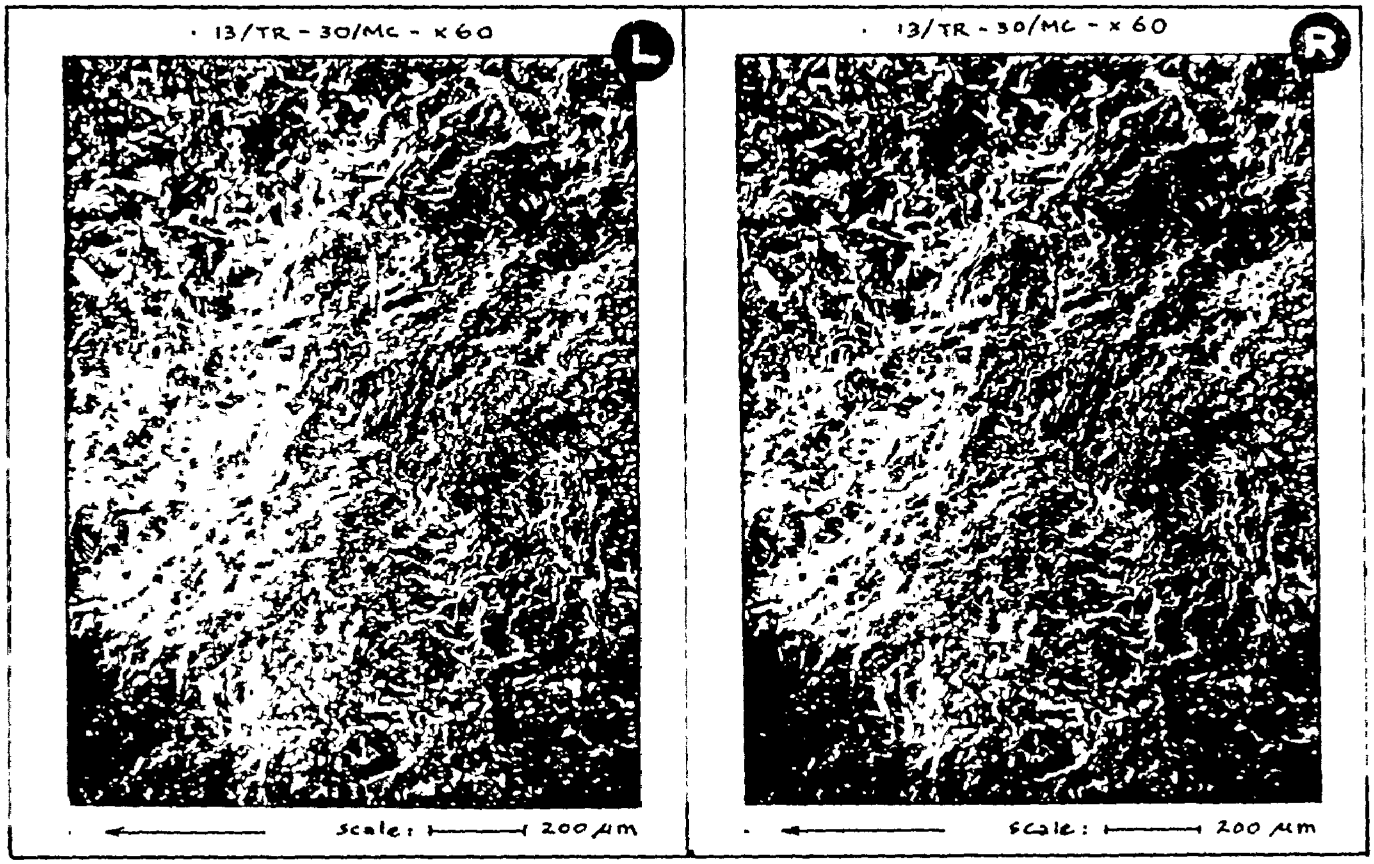
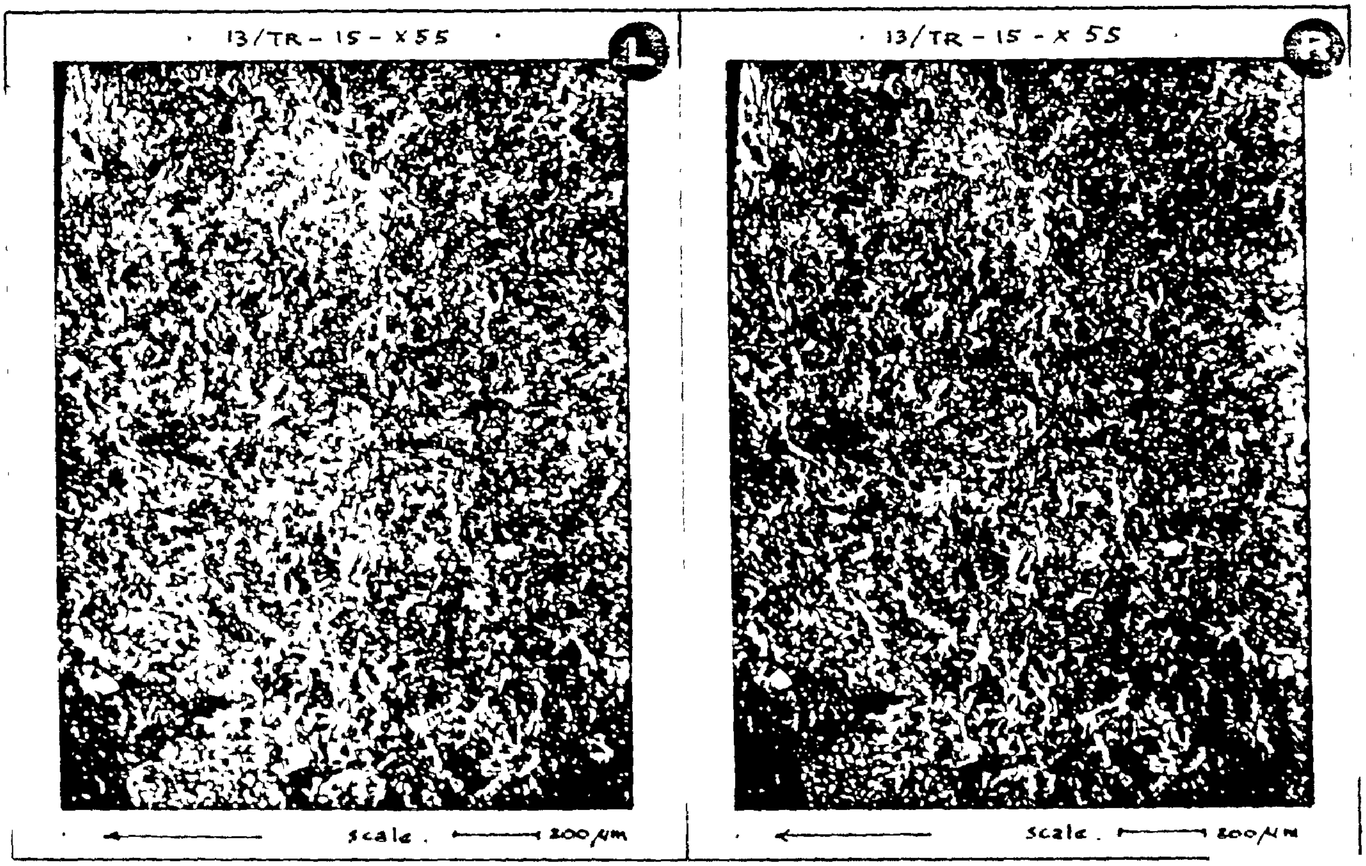


Figure 46. Typical Stereo-micrographs of Traprock (Open Graded) Test Section :13/TR

Pairs a. Fall 1978

Pairs b. Spring 1979



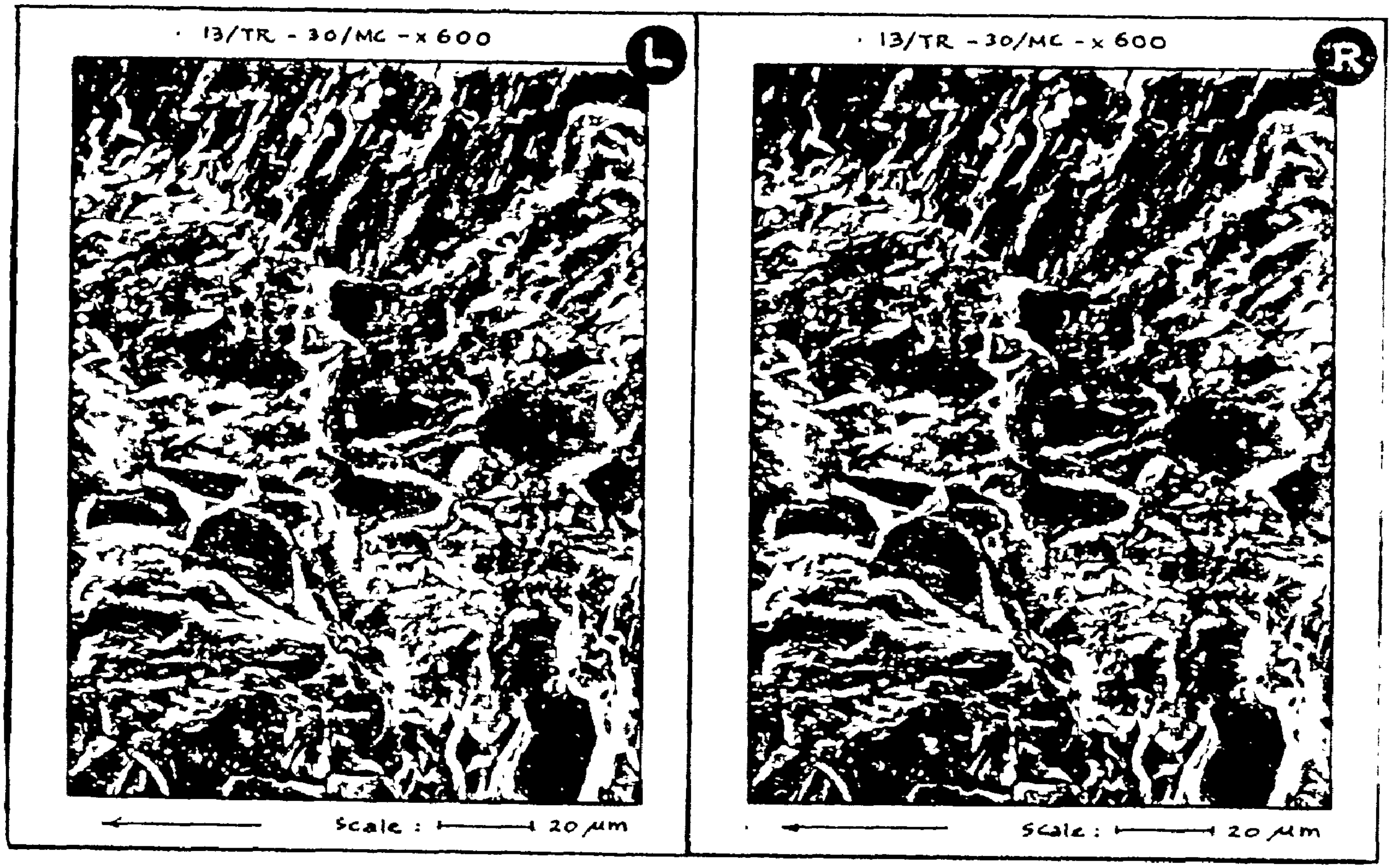
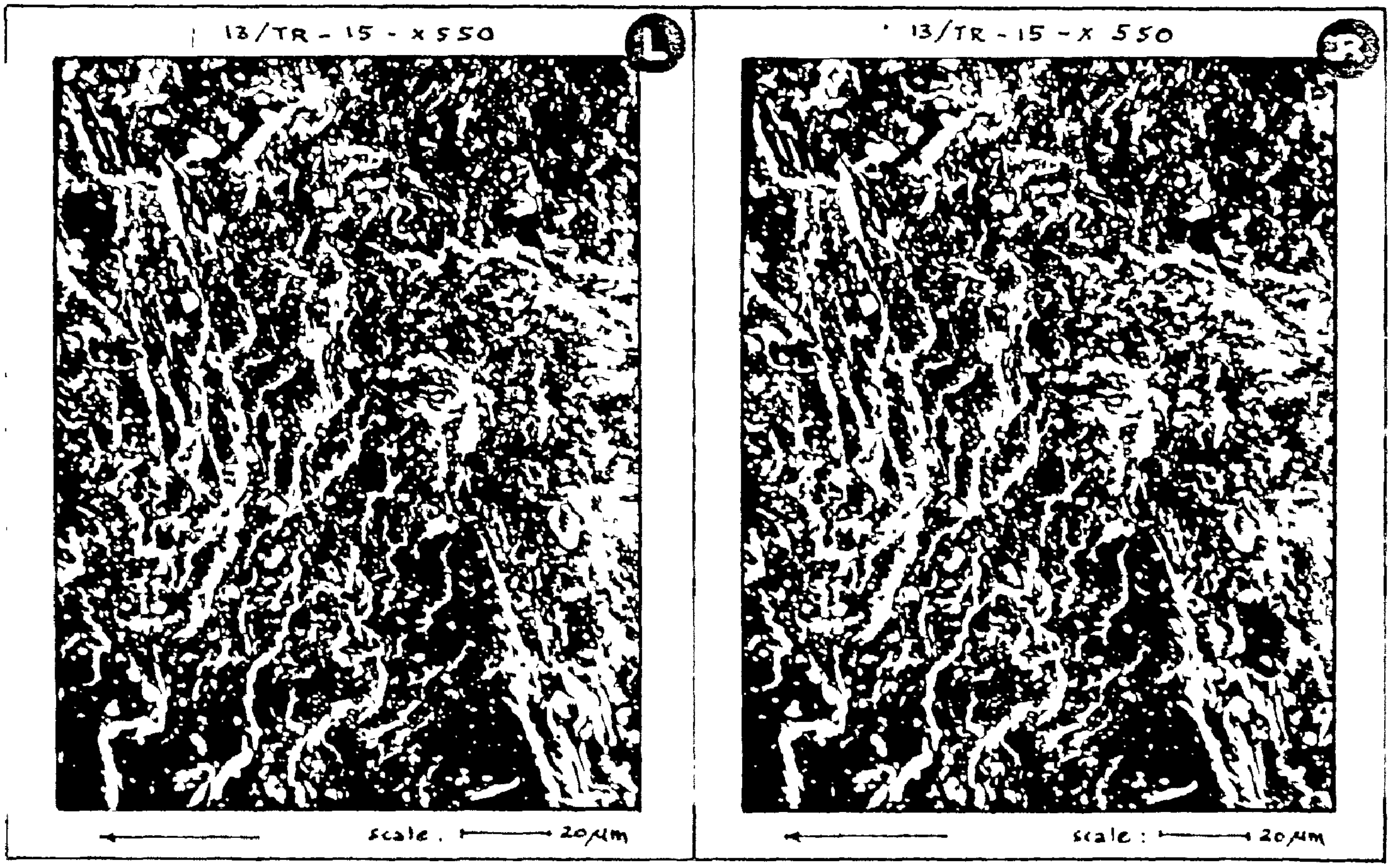


Figure 47. Typical Stereo-micrographs of Traprock (Open Graded) Test Section : 13/TR

Pairs a. Fall 1978

Pairs b. Spring 1979



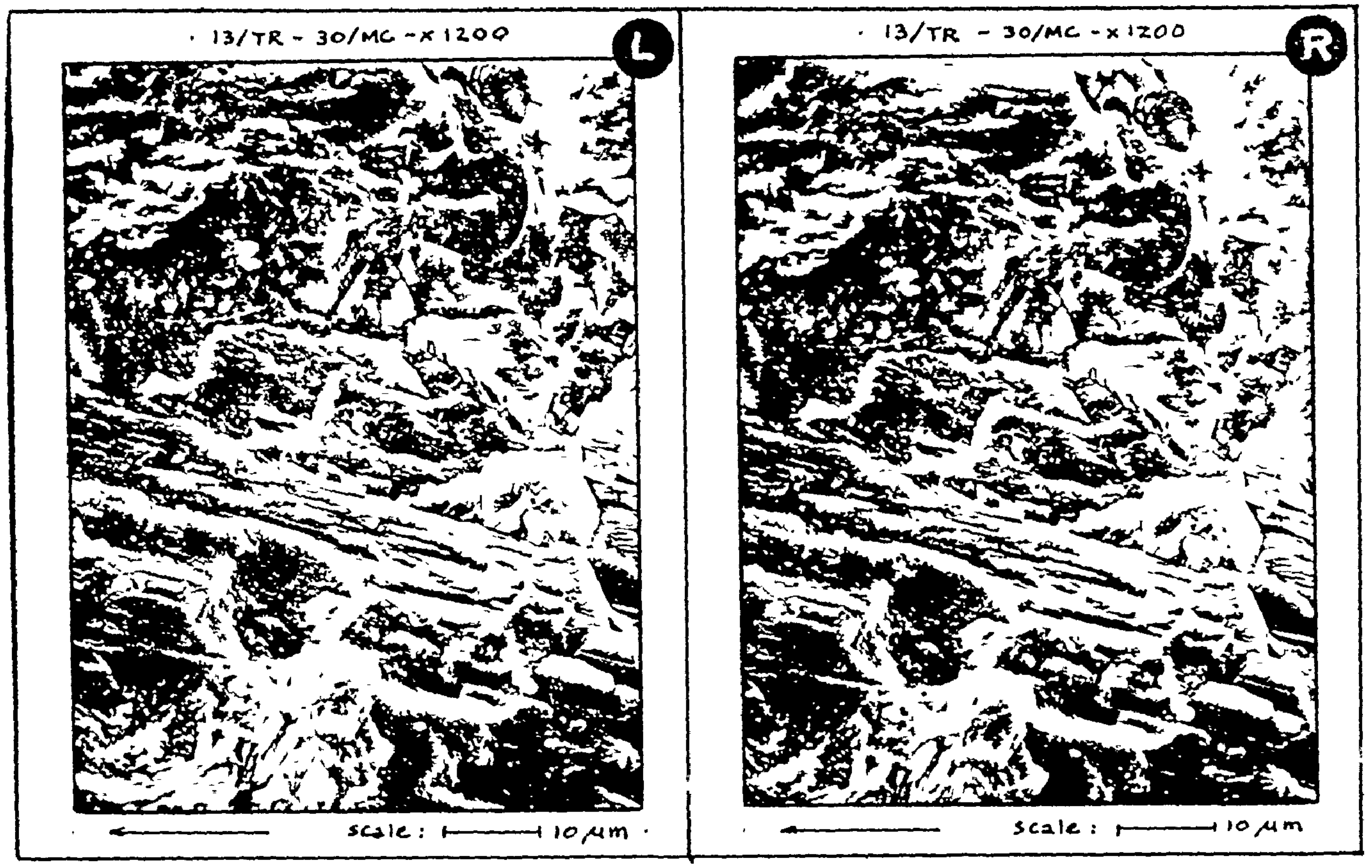
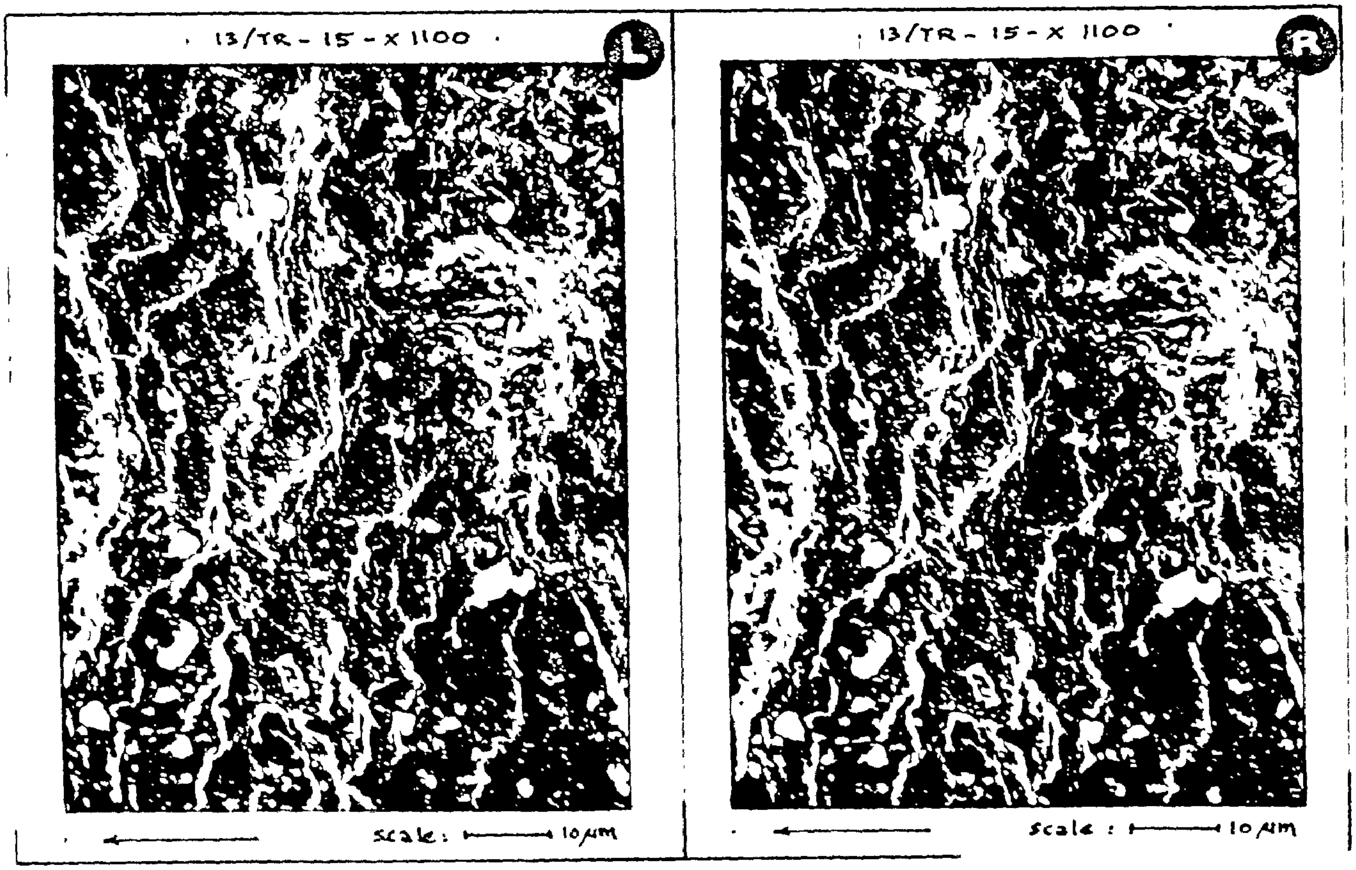


Figure 48. Typical Stereo-micrographs of Traprock (Open Graded) Test Section :13/TR

Pairs a. Fall 1973

Pairs b. Spring 1979



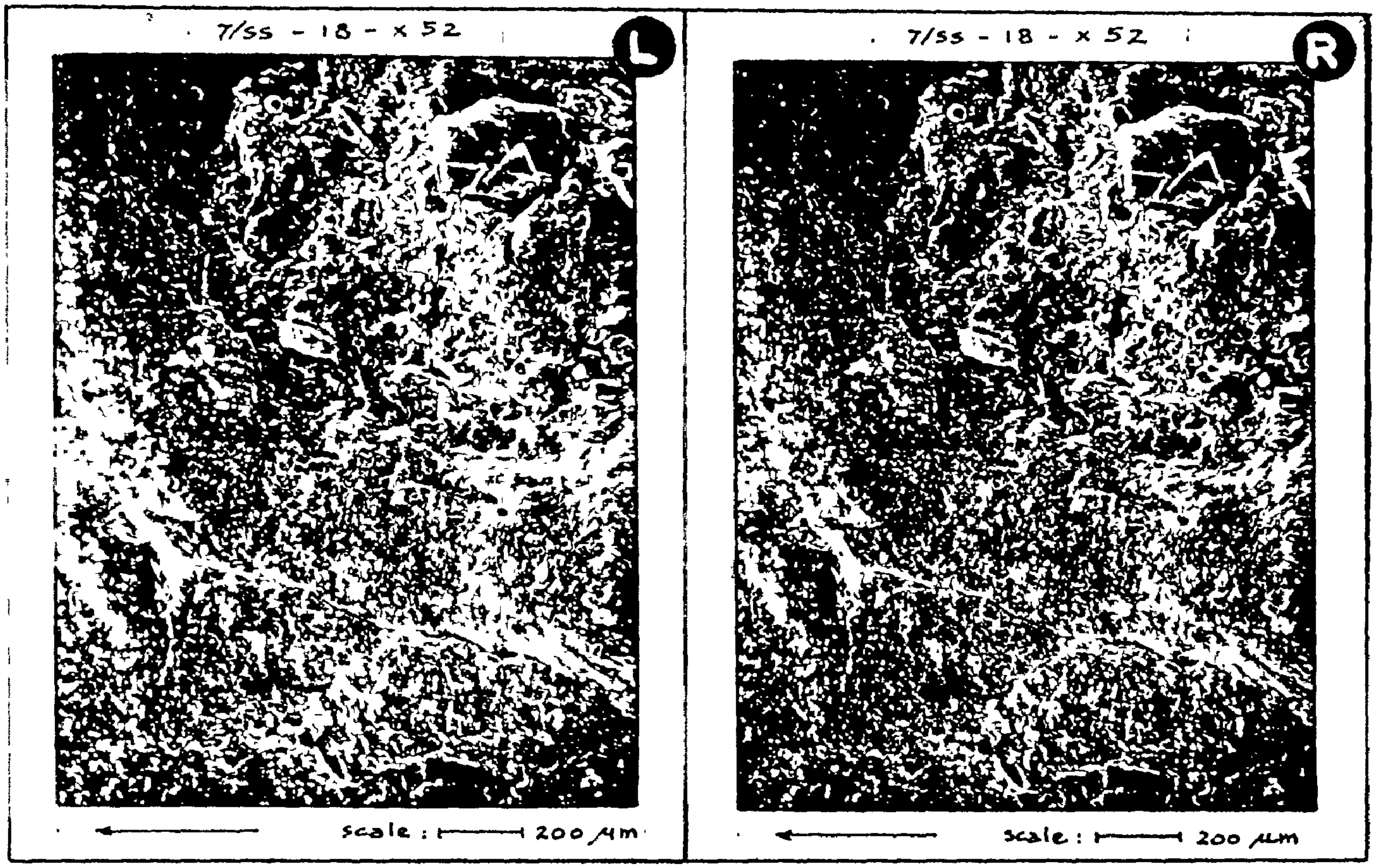
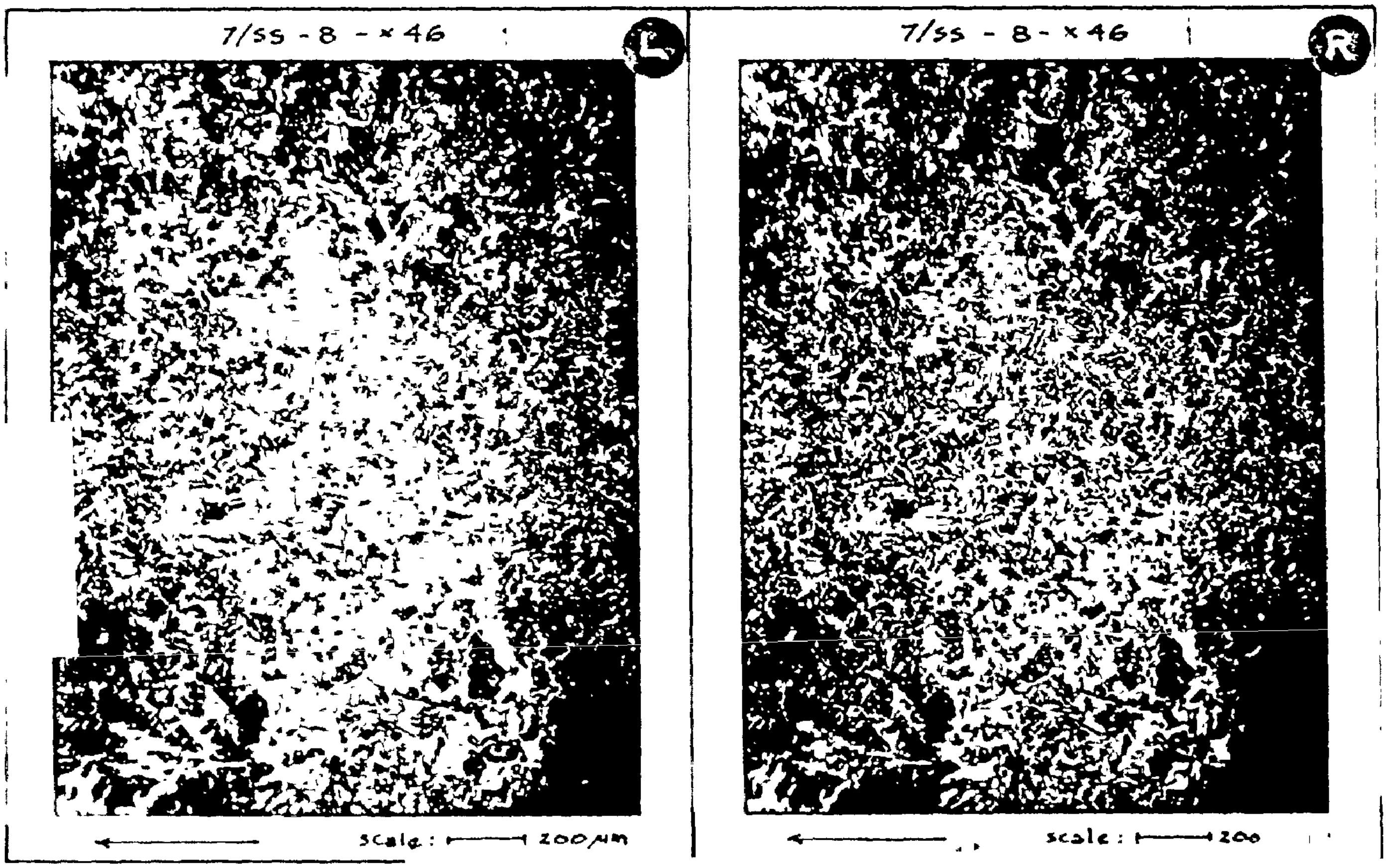


Figure 49. Typical Stereo-micrographs of Steel slag
Test Section : 7/SS

Pairs a. Fall 1978

Pairs b. Spring 1979



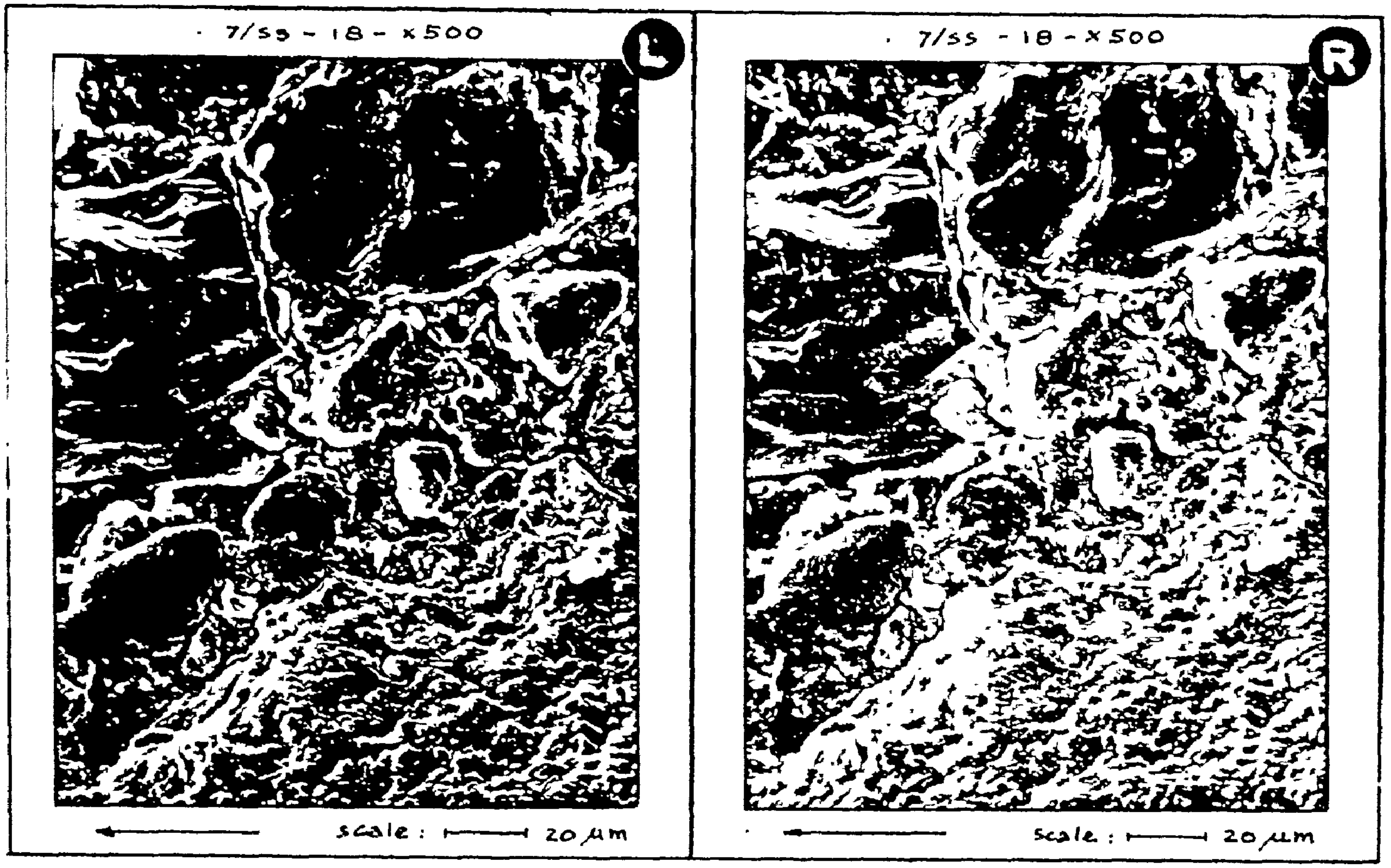
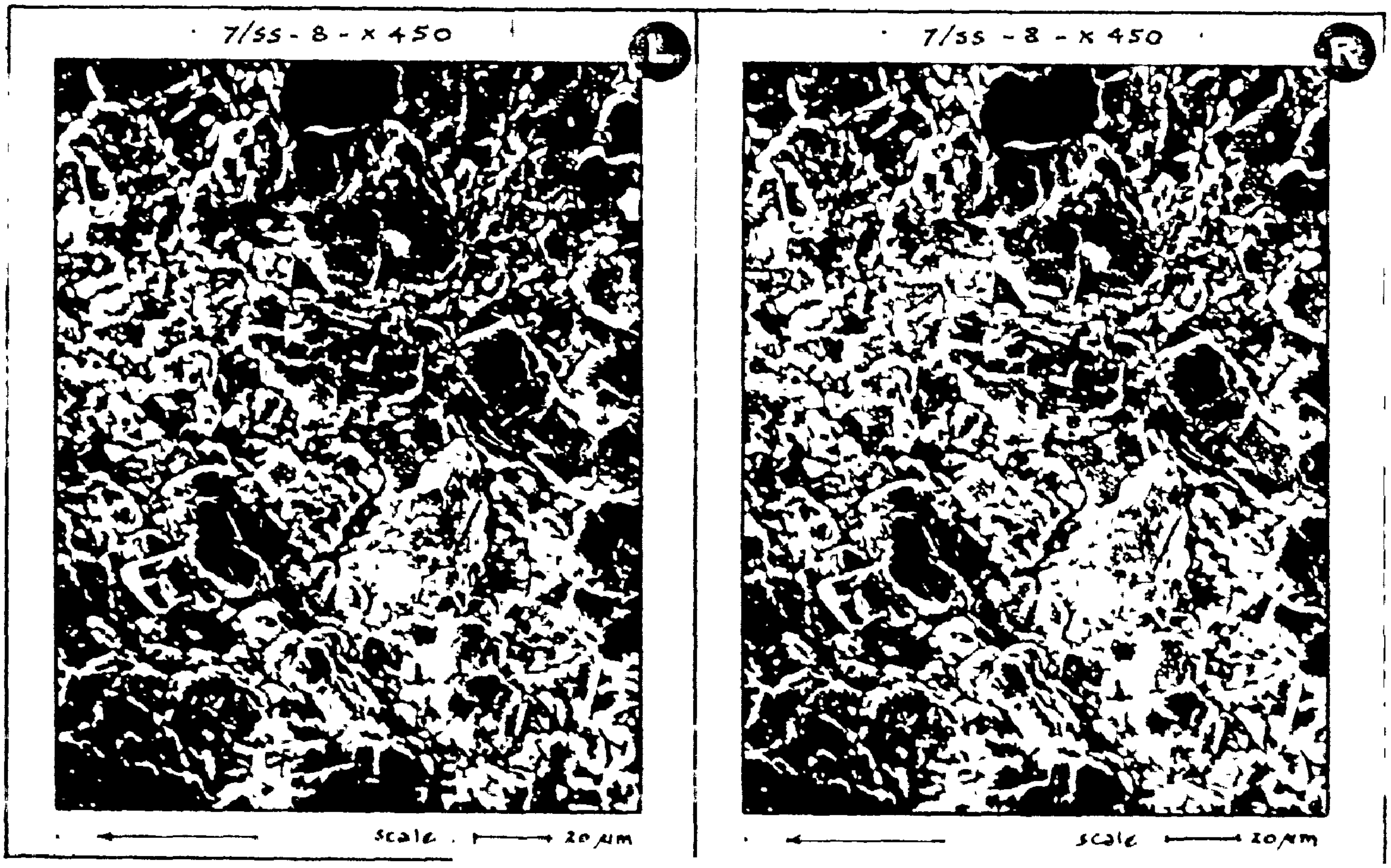


Figure 50. Typical Stereo-micrographs of Steel slag Test Section : 7/SS

Pairs a. Fall 1978

Pairs b. Spring 1979



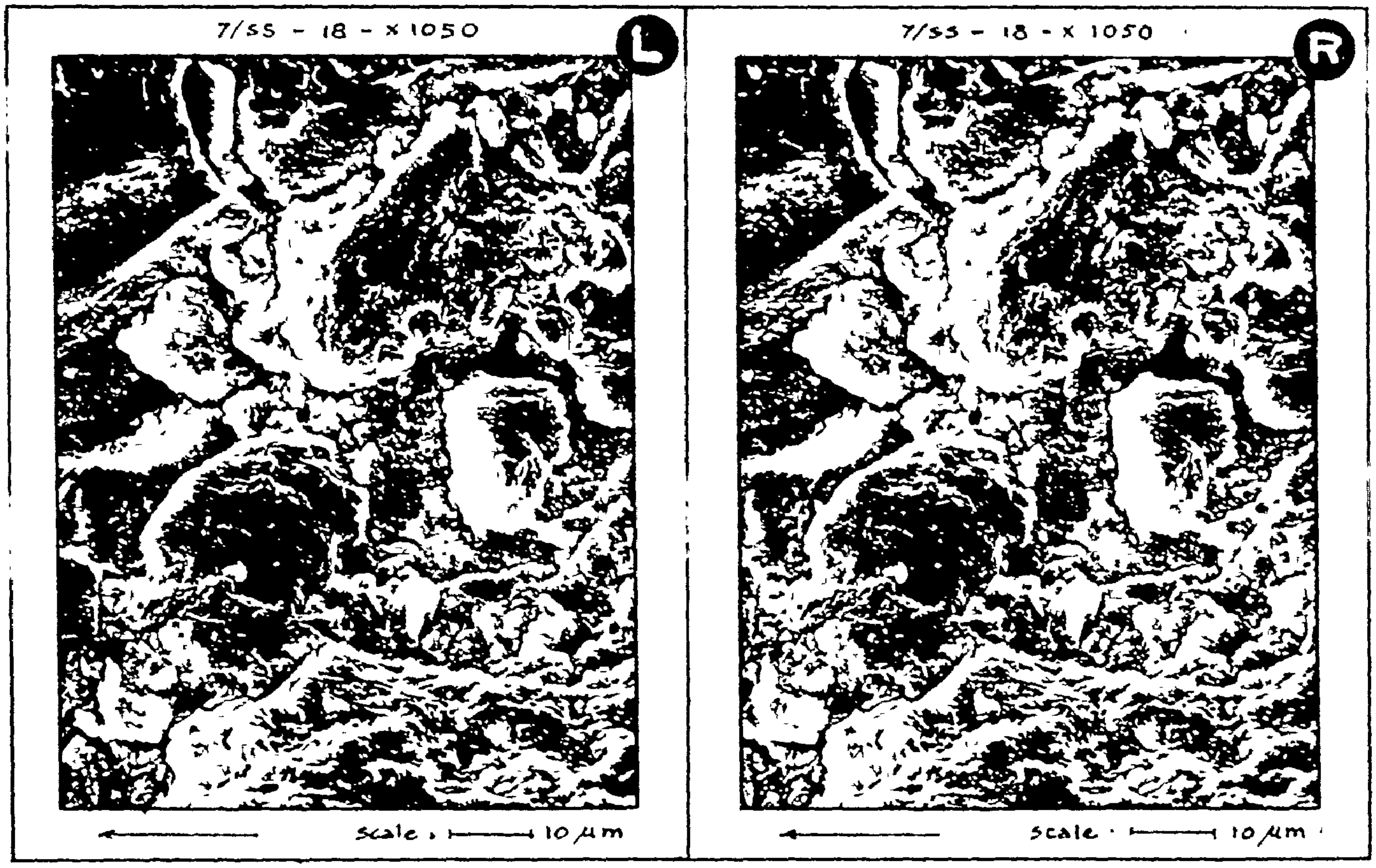
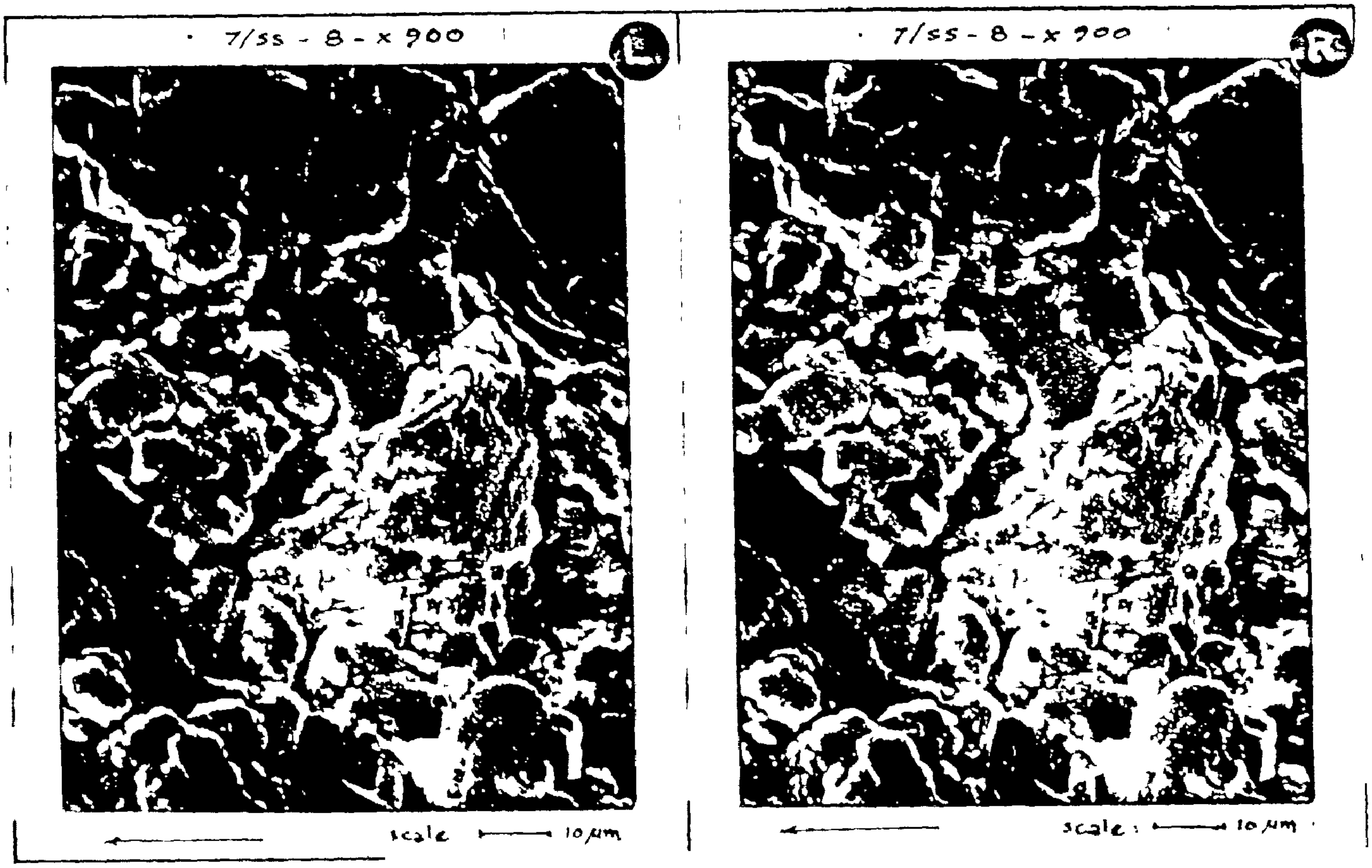


Figure 51. Typical Stereo-micrographs of Steel slag Test Section : 7/SS

Pairs a. Fall 1978

Pairs b. Spring 1979



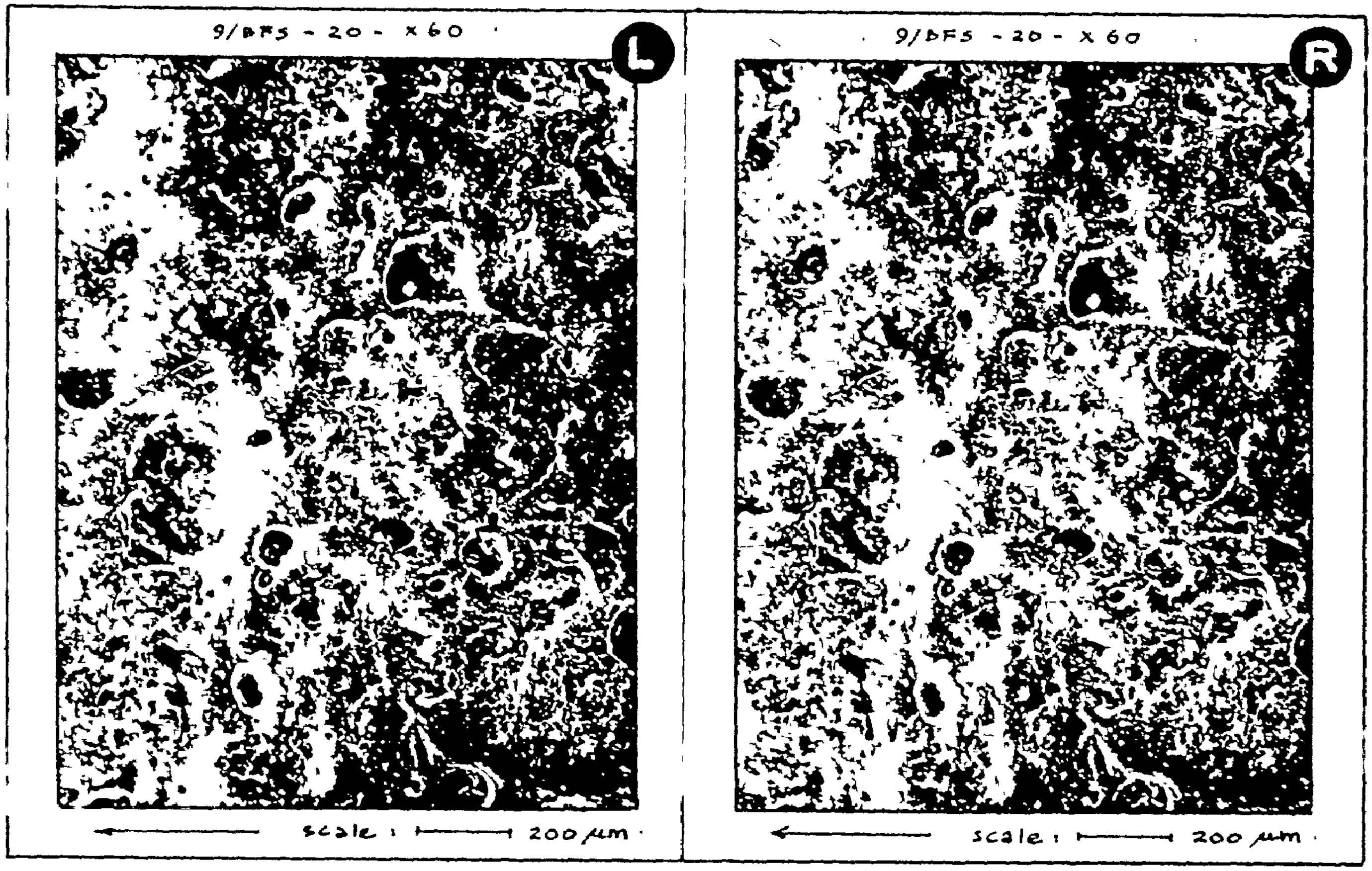
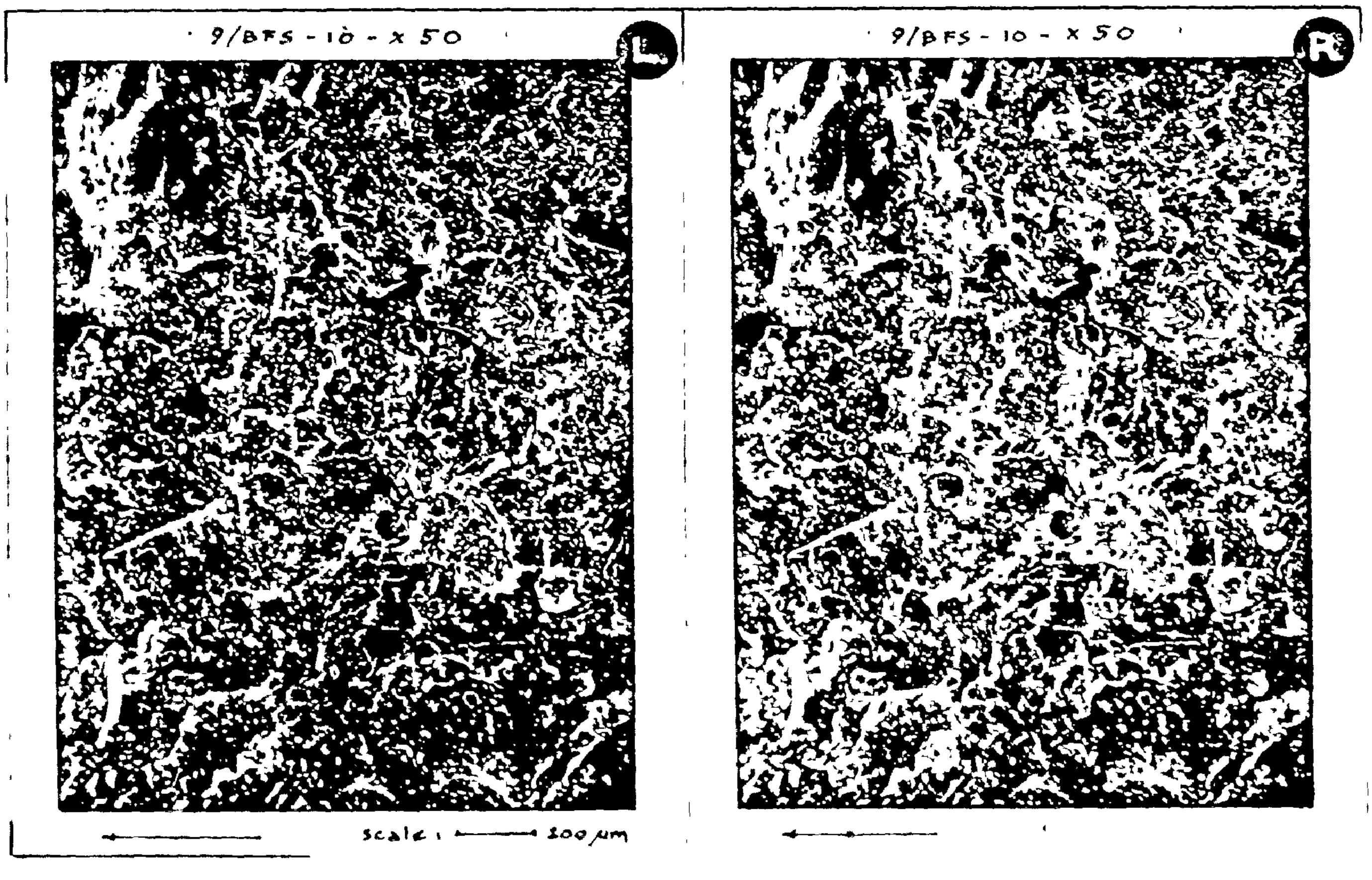


Figure 52. Typical Stereo-micrographs of Blast Furnace Slag Test Section : 9/BFS

Pairs a. Fall 1978

Pairs b. Spring 1979



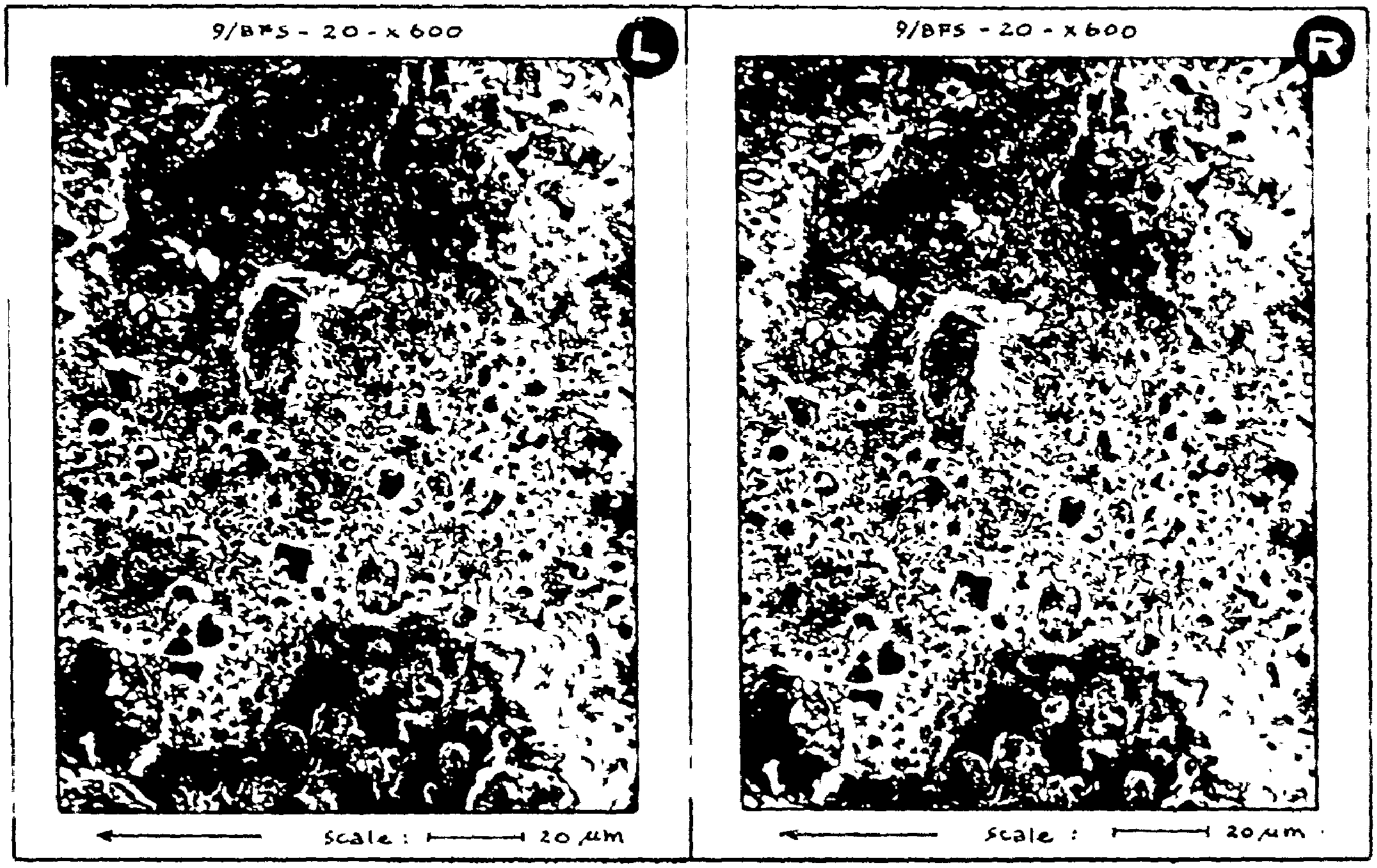
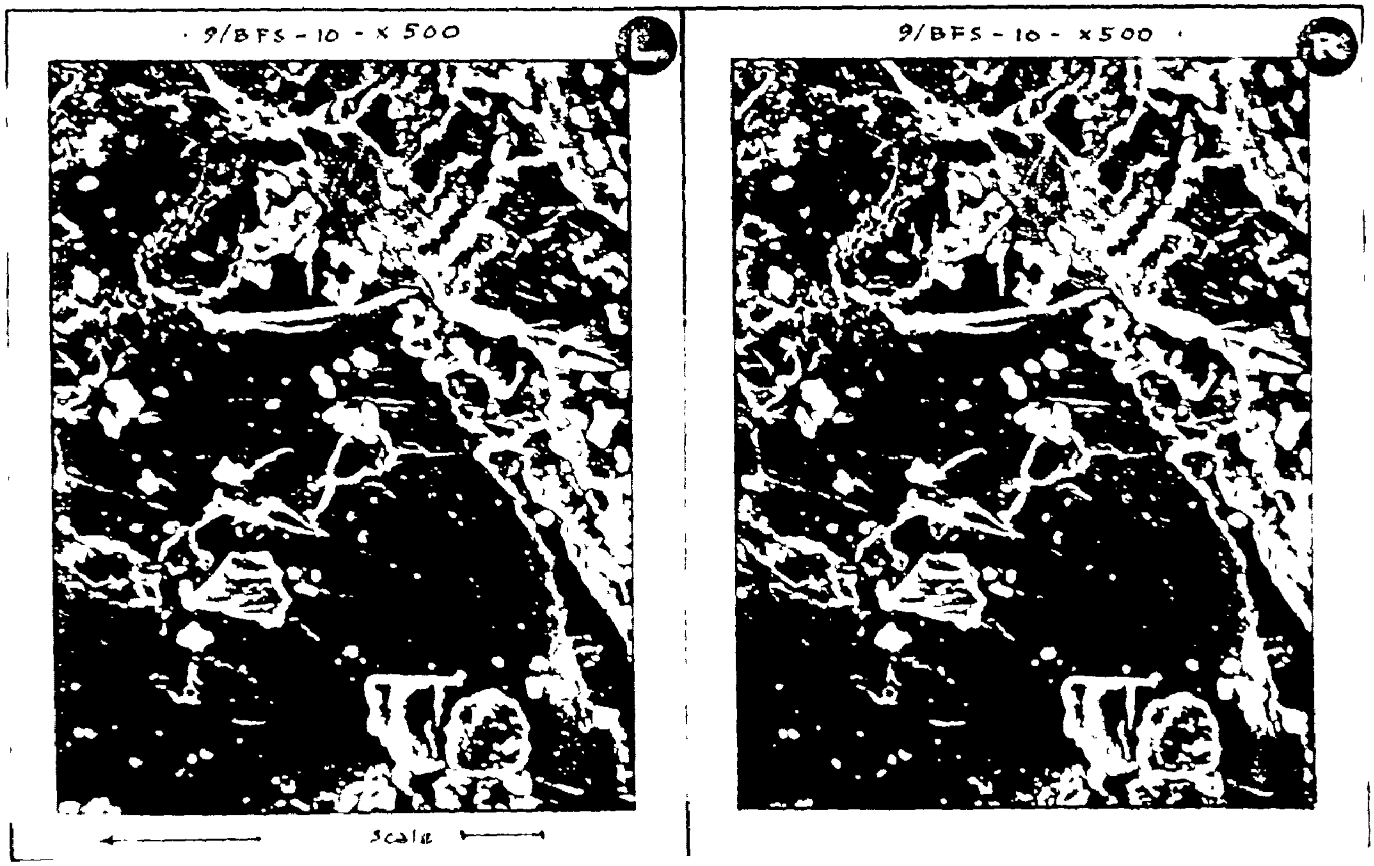


Figure 53. Typical Stereo-micrographs of Blast Furnace Slag Test Section : 9/BFS

Pairs a. Fall 1978

Pairs b. Spring 1979



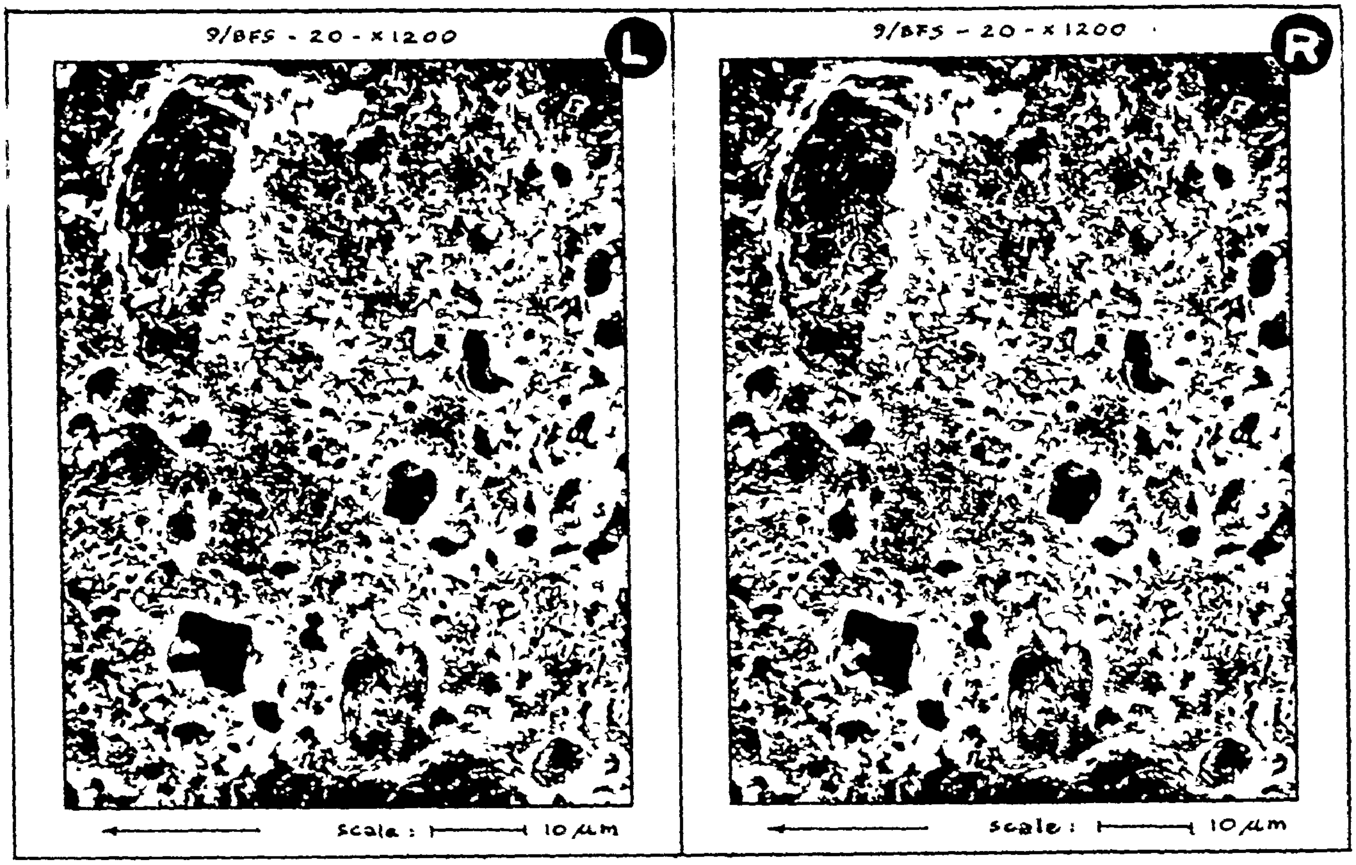
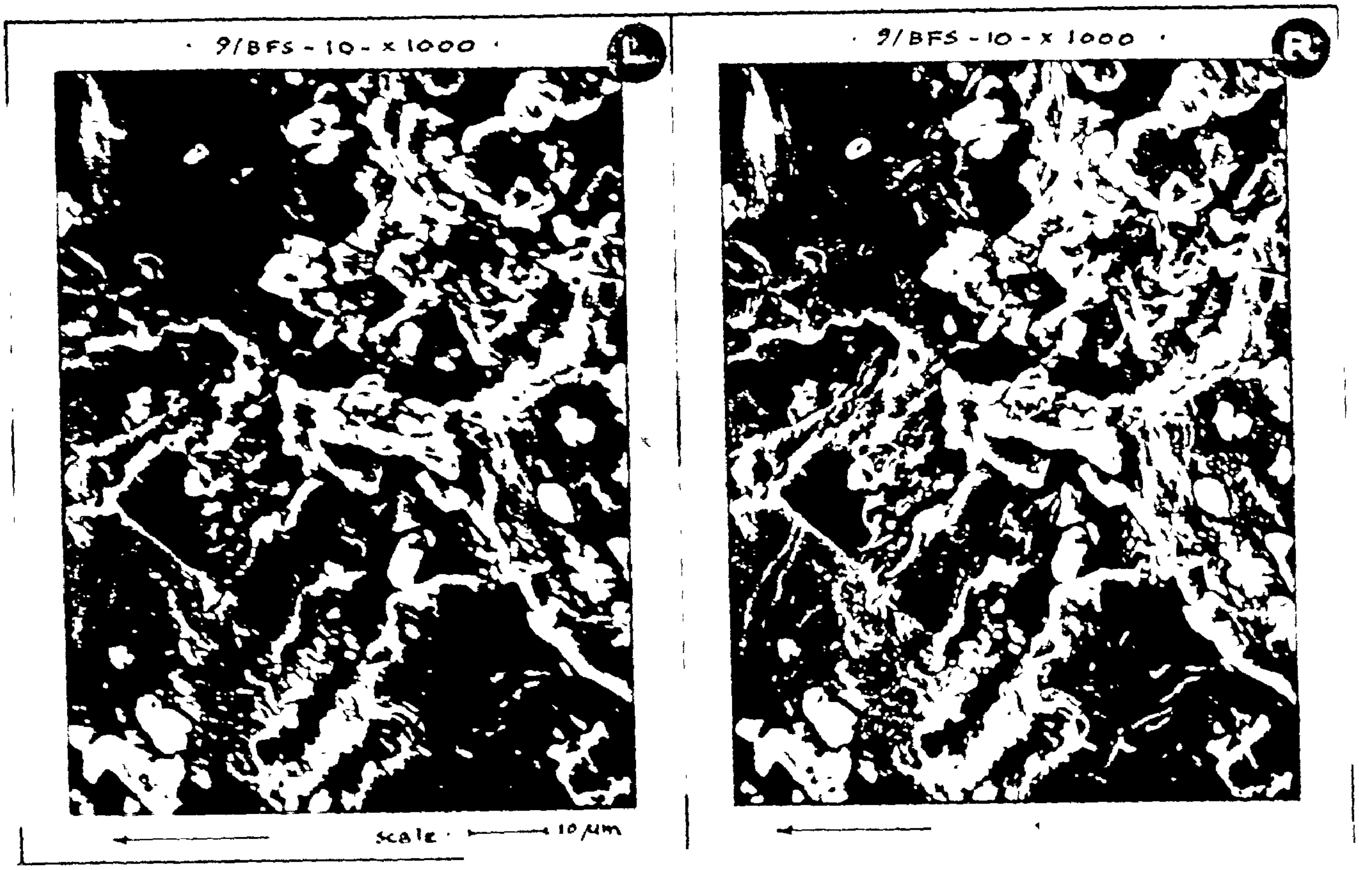


Figure 54. Typical Stereo-micrographs of Blast Furnace Slag Test Section : 9/BFS

Pairs a. Fall 1978

Pairs b. Spring 1979



used in open-graded mix are given in Figures 46 to 48. For comparison between the two types of mix, information is given in Appendix B. Typical stereomicrographs for the Stelco steel slag and blast furnace slag are given in Figures 49 to 51 and Figures 52 to 54 respectively.

In general, these stereomicrographs show that contaminants/crystals developed on the aggregate surfaces are found in abundance on observations of samples taken during the spring of 1979. In contrast, samples which were taken during the fall of 1978 contain little or no contaminants/crystals on the aggregate surfaces. The influence of the type of mix to the weathering effect is found to be insignificant, as found on observations between Figures 43 to 45 and Figures 46 to 48. Further observations and discussion are provided in the following sections.

4.3 OBSERVATIONS AND DISCUSSION

4.3.1 AGGREGATES MICROTEXTURE

The stereomicrograph is very useful to examine the microtexture of the aggregates. A summary of the primary and secondary microtexture of the samples is shown in both Tables 3 and 4. Table 3 gives the qualitative observations for the surface texture of the aggregates

Table 3. Qualitative Analyses of Core Samples Taken During the Fall of 1978

AGGREGATE	MICROGRAPH NO.*	PRIMARY MICROTEXTURE	SECONDARY MICROTEXTURE
TRAPROCK	1/TR-2	medium	low
	1/TR-4	high	medium
	1/TR-6	high	medium
	1/TR-6/MC	high	low
	3/TR-8	high	medium
	3/TR-10	medium	low
	3/TR-10/MC	high	high
	3/TR-12	medium	medium
	3/TR-12/MC	medium	medium
	13/TR-26	medium	low
	13/TR-28	high	medium
	13/TR-30	low	low
	13/TR-30/MC	low	low
STELCO STEEL SLAG	7/SS-14	medium	high
	7/SS-14/MC	medium	high
	7/SS-16	high	medium
	7/SS-18	high	high
	7/SS-18/MC+	low	low
BLAST FURNACE SLAG	9/BFS-20	low	low
	9/BFS-22	medium	medium
	9/BFS-24	high	high
	9/BFS-24/MC	high	high

Notes:

* the first number gives the Test Section No.

\+ Might be some inclusions.

Table 4. Qualitative Analyses of Core Samples Taken During the Spring of 1979

AGGREGATE	MICROGRAPH NO. *	PRIMARY MICROTEXTURE	SECONDARY MICROTEXTURE
TRAPROCK	1/TR-1	medium	medium
	1/TR-1B	medium	low
	1/TR-2	high	medium
	1/TR-2B	medium	medium
	1/TR-3	medium	medium
	1/TR-3B	low	low
	3/TR-4	medium	medium
	3/TR-4B	high	medium
	3/TR-5	medium	low
	3/TR-5B	medium	low
	3/TR-6	medium	low
	3/TR-6B	medium	medium
	13/TR-14	medium	low
	13/TR-14B	medium	medium
	13/TR-15	low	low
	13/TR-15B	low	low
STELCO STEEL SLAG	7/SS-7	high	medium
	7/SS-7B	high	high
	7/SS-8	high	medium
	7/SS-8B$^+$	low	medium
	7/SS-9	medium	medium
	7/SS-9B	high	medium
BLAST FURNACE SLAG	9/BFS-10	low	low
	9/BFS-10B	high	medium
	9/BFS-11	medium	low
	9/BFS-11B	medium	low
	9/BFS-12	low	low
	9/BFS-12B	medium	medium

Notes :

* For each core, there were two stubs made (ie. two different stones)

\+ Might be inclusions.

taken from the fall of 1978 cores, whereas Table 4 gives similar observations for the spring of 1979 cores.

The importance of primary and secondary microtexture to skid resistance has been emphasized by Gutt and Nixon (7). As mentioned in Chapter 3, the primary microtexture is the surface texture on the scale of 10 to 50 μm, whereas the secondary microtexture is the surface texture on the scale of 1 to 5 μm. It has been found that the observation of secondary microtexture is not biased at higher magnifications. Therefore, most of the stereomicrographs which were taken for the spring of 1979 cores were taken at higher magnifications than the fall of 1978 core samples.

4.3.2 DIRECTION OF TRAFFIC

The cores obtained during the fall of 1978 were marked for the direction of the traffic; however, the cores obtained during the spring of 1979 were not marked at all. Some useful observations can be made with regard to the traffic direction, which were matched to the initial marks given on the fall 1978 cores. These observations are:

1. If the polishing process is not too severe, and the aggregate has a low abrasion value (i.e., high resistance to abrasion), the traffic direction can be readily determined.
2. The traffic direction can be observed from the side where the texture is polished. This is explained in Figure 55.

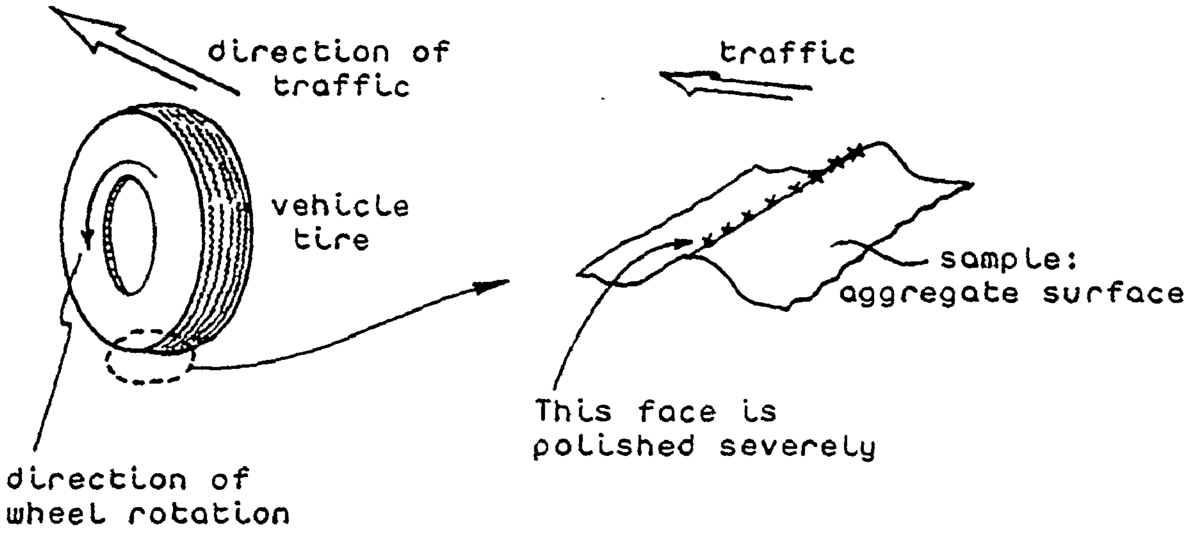


Figure 55. Polishing and Direction of Traffic

3. For aggregates with a high abrasion value, such as blast furnace slag, the observation of traffic direction is somewhat difficult. For this case, careful observation, as well as observation at higher magnifications are required to find the traffic direction. Observations around porous areas, depressed edges and grooves are sometimes useful.

These observations were found very useful in determining the orientation of the aggregate samples from the cores taken during spring of 1979.

4.3.3 ASPHALT CEMENT CONTAMINATION

In the initial work, which was the evaluation of core samples taken during the fall of 1978, two types of aggregate samples were examined:

1. Aggregate samples which were cleaned ultrasonically in water to remove contamination such as dust.
2. Aggregate samples which were cleaned ultrasonically in an organic solvent (M- Clean -D or MC), so that any asphalt cement on the surface of the stone was removed.

In this initial work, it was found that there was no great difference observed for samples cleaned in solvent or water. The asphalt cement had been worn and removed from the surface of the aggregates at the early stages of the polishing and abrasion by traffic. Therefore, in the second stage of the work with core samples taken during spring of 1979, only ultrasonic cleaning in water was used.

4.3.4 TRAFFIC APPLICATIONS

Traffic data for the test section is available and summarized in Table 5 (9). The observation for both fall and spring cores indicate that in most cases it is not possible to tell whether the samples were taken from the passing or driving lane. Furthermore, it is also not possible to tell whether they are taken from the between wheel path or in wheel path area of the lane. This is probably due to the application of considerable amount of heavy traffic on the Toronto Bypass, that the effect of traffic application to the aggregate is almost equal between lanes or wheel paths.

Table 5. Traffic Data from Highway 401 Test Sections

TYPE OF LANE	AADT	PERCENT COMMERCIAL
Driving Lane	12900	29
Passing Lane	14600	1

4.3.5 SURFACE TEXTURE AND AGGREGATES

The qualitative analyses of the surface texture for each observation were given in Tables 3 and 4. Basically, the primary and secondary microtexture of the aggregates can be summarized as follows:

1. There is not much difference between aggregates taken during the fall and spring. The only apparent difference lies in the amount of contaminants and/or crystals formed on the surface of the aggregate during spring time.
2. Observations on surface texture of the aggregates for both fall and spring time are summarized and given in Table 6.

Table 6. Summary of Surface Texture Aggregate of Core Samples Taken During Fall and Spring Term on Highway 401 Test Sections

AGGREGATE	PRIMARY MICROTEXTURE	SECONDARY MICROTEXTURE
TRAPROCK :		
Test Sections 1,3	medium to high	low to medium
Test Section 13	low to medium	low
STELCO STEEL SLAG	medium to high	medium
BLAST FURNACE SLAG	varies : low - medium - high	varies : low - medium - high

3. The evaluation of blast furnace slag and steel slag can be easily biased by the presence of inclusions, impurities and other soft by-product materials.

4.3.6 PSV AND SURFACE TEXTURE

The results of previous PSV testing for the aggregates considered were (9):

Traprock	PSV = 45
Steel slag (Stelco OH)	PSV = 59
Blast furnace slag	PSV = 54.

A previous SEM study (7) of aggregates indicated the best PSV is obtained when the surface has a good secondary microtesture, which is superimposed on a good primary microtexture. Further, it was found that a good primary microtexture alone will give a moderately good PSV. An extremely high PSV (up to PSV of 90) is related to materials with good primary and secondary microtexture, plus high resistance to polishing and abrasion.

While these findings are important, the results from the Highway 401 Test Section micrographs indicate that there might be another factor which is related to the PSV of aggregates. The PSV of aggregates might be governed only by a small (minimum) amount of the aggregate which has a very high skid resistance quality (i.e., primary or secondary microtexture). This might be true for the case of steel slag and blast furnace slag where there are inclusions of limestone, weak particles, etc.

4.3.7 WEATHERING EFFECT

It was generally observed that the aggregate samples from cores which were taken during the spring of 1979 had more contaminants and/or crystals on the surface than the ones obtained during the fall of 1978. In order to analyze these surface contaminants/crystals, XRD analyses were completed on all of the spring of 1979 samples. The results of the XRD analyses are given in Appendix E, and can be summarized as follows:

1. Traprock

   The amount of contaminants was limited, which indicates the "stability" of traprock against weathering. The elements found in the contaminants/crystals were mainly Si, Ca, Fe and Al. These elements are similar to the ones found in previous chapter , and they are probably constituents of the traprock itself which leach during the process of weathering.

2. Steel Slag

The dominant elements of the contaminants were Ca, Fe, Si and Al. These contaminants might have been in the form of CaO, MgO, Rankinite ($3CaO.2SiO_2$) and Merwinite ($3CaO.MgO.2SiO_2$).

3. Blast Furnace Slag

The dominant elements in the contaminants/crystals were almost similar to steel slag, except the amount of Fe element is not as abundant as in steel slag. The forms of crystal which may have been formed were Akermanite ($2CaO.MgO.2SiO_2$) or Gehlenite ($2CaO.Al_2O_3.SiO_2$).

Finally, the weathering study on aggregate surfaces by using XRD diffraction analysis in this chapter revealed similar findings with simulated weathering study as described in Chapter 3. Both studies show that simulated weathering can be used to represent the actual weathering obtained by precipitation on the actual road conditions.

5 WEATHERING AND SKID RESISTANCE

5.1 INTRODUCTION

Besides the processes of polishing and abrasion, weathering is important to skid resistance performance as indicated in the laboratory study of Chapter 3. Generally, the weathering process is related to the restoration of the microtexture, which can considerably alter the skid resistance performance of the pavement. The weathering process, which has chemical and physical components, depends on environment, location, season, etc. Therefore, weathering is one of the important factors which contributes to seasonal variation in skid resistance (17).

5.2 SEASONAL VARIATIONS IN SKID RESISTANCE

Generally, it is found that the skid resistance of a pavement is highest during the winter season, and lowest during the dry mid-summer season (17, 18, 19).

Tests conducted during the period of spring through fall also revealed that the skid resistance can vary by as much as 25 percent during a single week (19). This shows that variations in skid resistance do not only occur from season to season, but also under very short term conditions, such as weekly or daily variations in weather and traffic.

The seasonal and short term variations may be caused by two factors (17):

a. the change in properties of rubber tires, which may be related to the temperature variations; and

b. the change in the surface texture of the pavement.

In the first case, temperature changes from time to time affect the properties of rubber tires. Some studies found that the resilience of rubber tires increases as the temperature increases. As a result, the resistance to skidding will tend to decrease (20, 21). However, another study found no temperature influences on skid resistance performance (19).

In the second case, the change of surface texture is associated with the observed variations in skid resistance. This change is attributed to various mechanisms, such as polishing, abrasion and weathering. However, weathering may be the most influential mechanism for the seasonal and short term variations in skid resistance.

Rainfall, for example, depends on the season and can also vary from time to time within the season. Figures 56 and 57 show typical examples of variations in skid resistance observed during studies in the United States. In Figure 56, the variations of skid numbers for three pavements in Pennsylvania were observed for an 8-month period (19). Figure 57 shows the similar type of variations on a highway strip for two-month period (22).

5.3 WEATHERING PROCESS

5.3.1 DEFINITION

Weathering is a process in which the aggregate is "disintegrated" to a more stable condition in its physical and/or chemical characteristics. As a more specific term, which is related to skid resistance performance, the weathering process includes all factors due to natural, artificial and man-made changes in the overall environment of the pavement in addition to polishing and wear by the traffic.

The process of weathering can be divided into two categories:

a. chemical weathering; and

b. physical weathering.

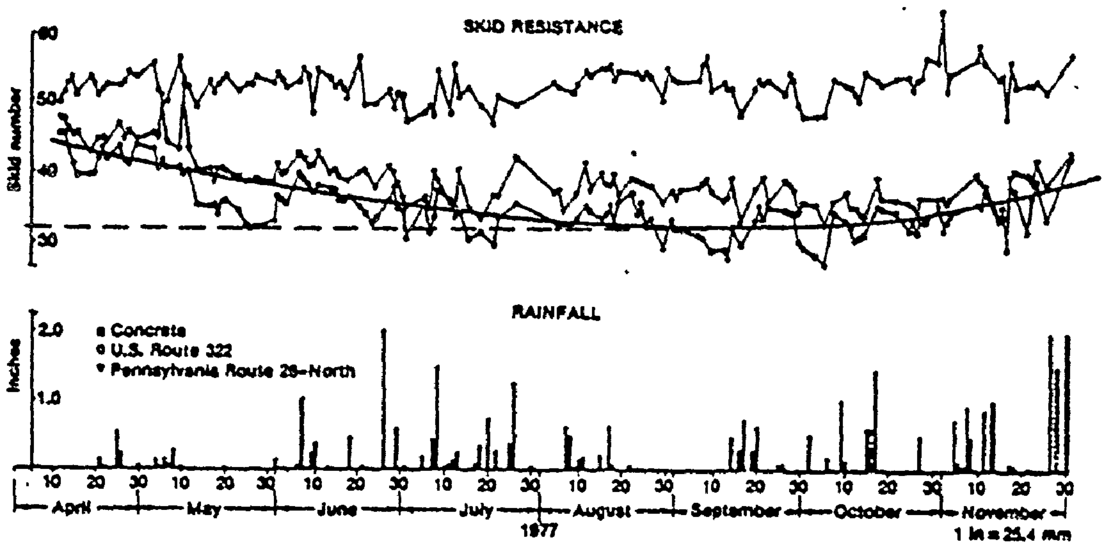


Figure 56. Skid Resistance Performances for Three Pavements over an 8-month Period (19)

Figure 57. Influence of Precipitation on Skid Resistance, Observed over a 2-month Period (22)

5.3.2 CHEMICAL WEATHERING

Chemical weathering is the process of breaking down the mineral constituents of rocks into more stable new mineral phases. With the growth of urban industrialization, gaseous, liquid and solid waste generation has resulted in a greater chance to accelerate the process of chemical weathering of road surfaces. Therefore, chemical weathering which was usually caused by nature only, is now complicated by the pollution created by man.

Chemical weathering of pavement surface is related to one of the following:

1. Pure Water Attack

   The existence of water on the pavement surface not only reduced the available skid resistance, it can also cause chemical reactions with the aggregate. The extent of this attack depends particularly on the chemical characteristics of the aggregate. Furthermore, with the introduction of artificial aggregates, such as steel slag and blast furnace slag, water may have a greater influence on the chemical weathering process.

2. Rainwater Attack

   In industrial areas, the rainfall water is usually contaminated with substances which are exhausted by industries, cars, incinerators and many other man-made activities. For instance, acid rain is a well-known problem; and it can accelerate the weathering of pavement surfaces.

3. Effect of Salting During Winter Periods

The use of salt ($CaCl_2$ or NaCl) to melt the ice on highways can also result in changes in skid resistance performance. Salt may also react with some substances in the aggregate and therefore cause chemical weathering.

5.3.3 PHYSICAL WEATHERING

Unlike chemical weathering, physical weathering is a disintegration process of the parent rock without any change in its chemical composition. In particular, it usually refers to the process of breaking down the aggregate due to physical changes, such as volume or temperature variations. Such changes can occur if the aggregates are subjected to cyclic wetting and drying for long periods of time. Furthermore, freeze and thaw cycles can also promote physical weathering, especially for porous aggregates where water can be trapped in the pores. This is, of course, coupled with direct tire action in forms of polishing and abrasion. In this study, physical weathering was not emphasized, although its importance is recognized.

5.3.4 OBSERVATION OF WEATHERING EFFECTS ON THE HIGHWAY 401 TEST SECTIONS

As part of a program to study skid resistance and its evaluation for Ontario aggregates, 18 asphaltic concrete test sections were constructed in 1974 on Highway 401, North of Toronto. Further information regarding the test sections is given in Appendix B.

Between 1974 and 1978, seasonal readings of the skid numbers for the test sections were obtained using the ASTM brake-force trailer. These tests were carried out in the wheel path of each lane at speeds of 30 mph and 60 mph, and reported as SN_{30} and SN_{60}, respectively. Basically, three types of coarse aggregate were used in the test sections: traprock, Stelco steel slag, and blast furnace slag. Typical plots of skid number with time are given in Figures 58 to 61. The rest of the plots are given in Appendix C. To consider the seasonal variation of the environment, monthly accumulative precipitation plots are also included in Figures 58 to 61. These precipitation readings were obtained from Downsview Airport, which is the closest Meteorological Station to the test sections (23).

In the four figures, readings were taken for the driving lane of the test sections. Figure 58 refers to Test Section 2, which involved traprock as the coarse

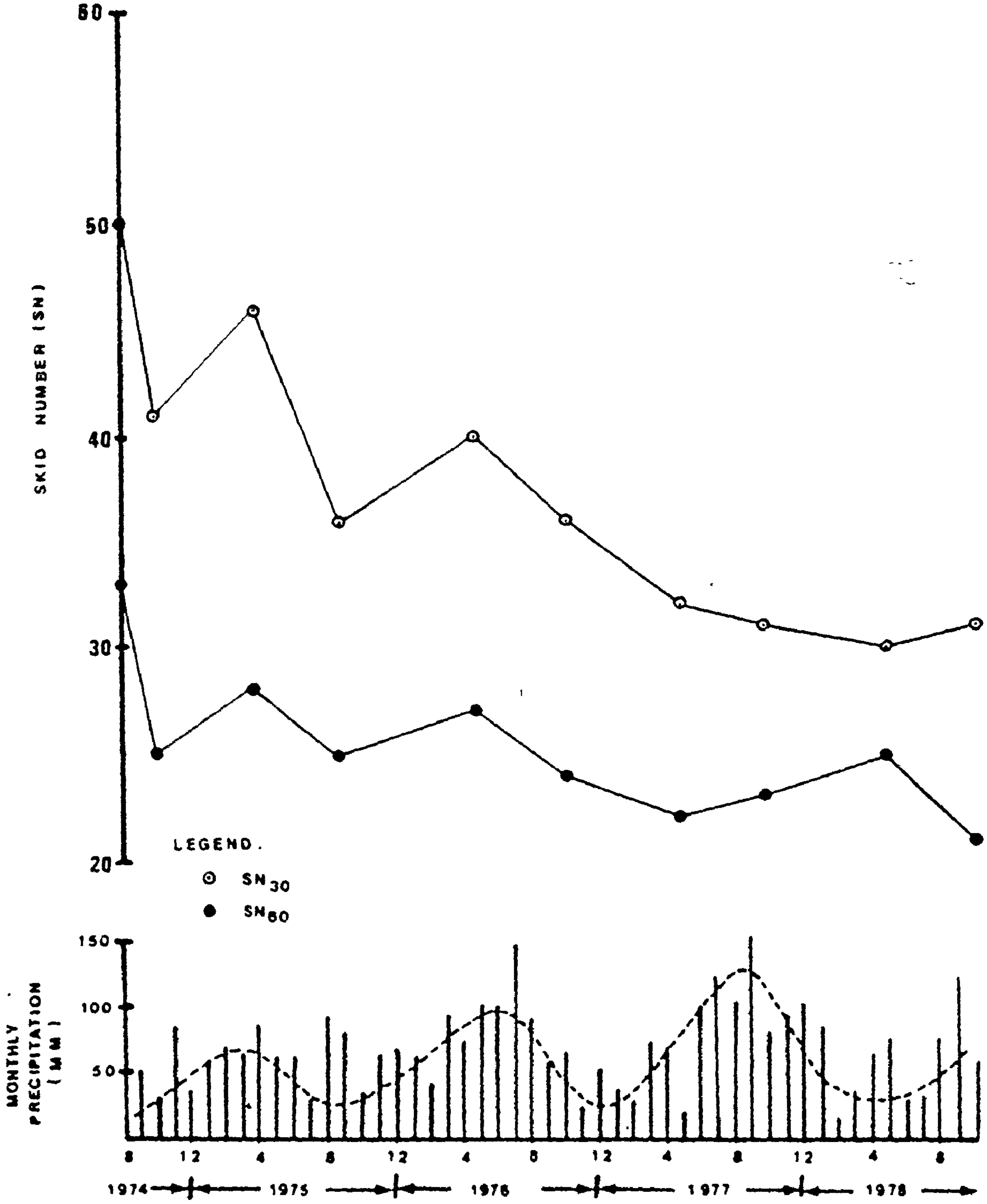


Figure 58. Skid Resistance Performance of Highway 401 Test Section No. 2 (Traprock), Driving Lane

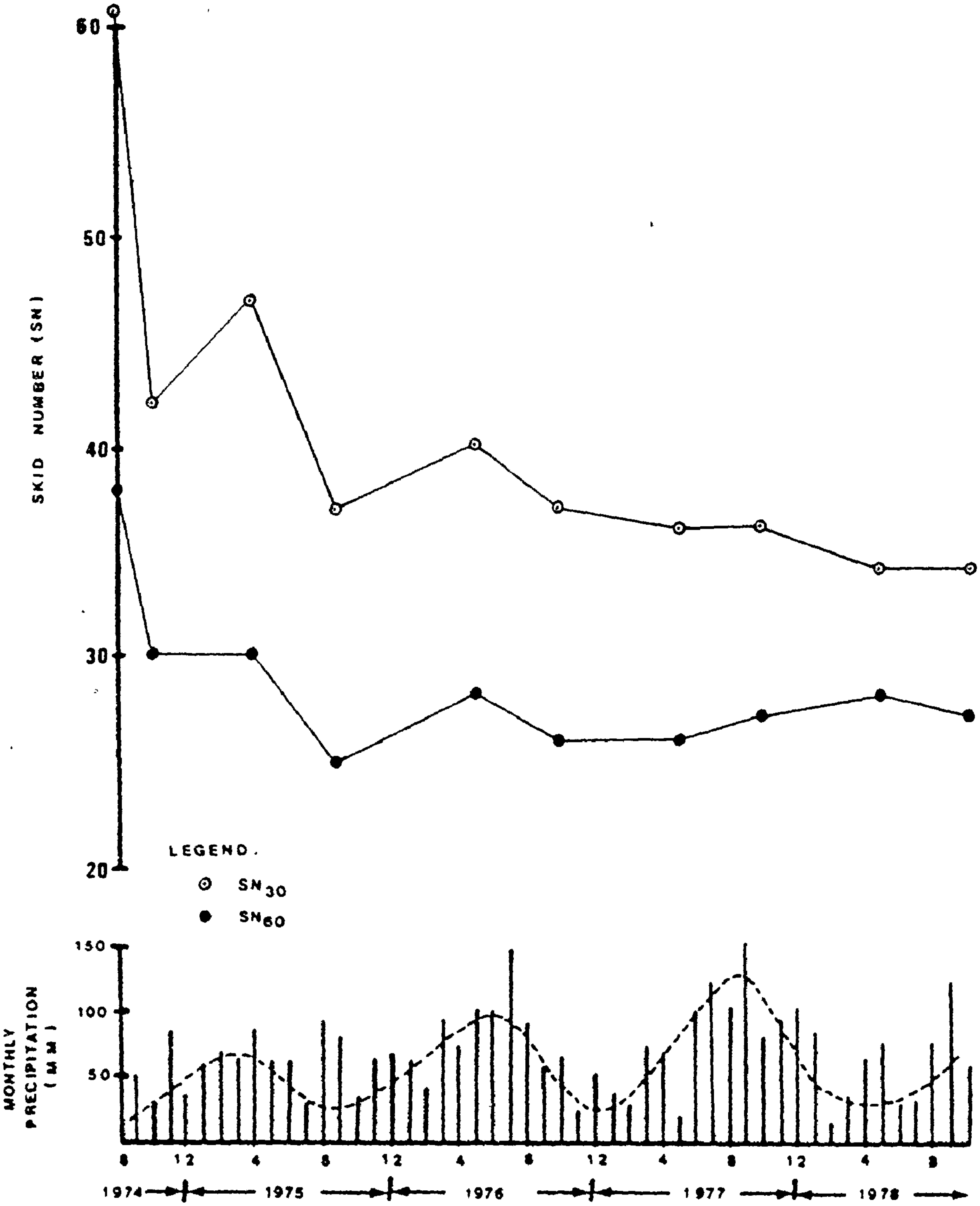


Figure 59. Skid Resistance Performance of Highway 401 Test Section No. 8 (Stelco Steel Slag), Driving Lane

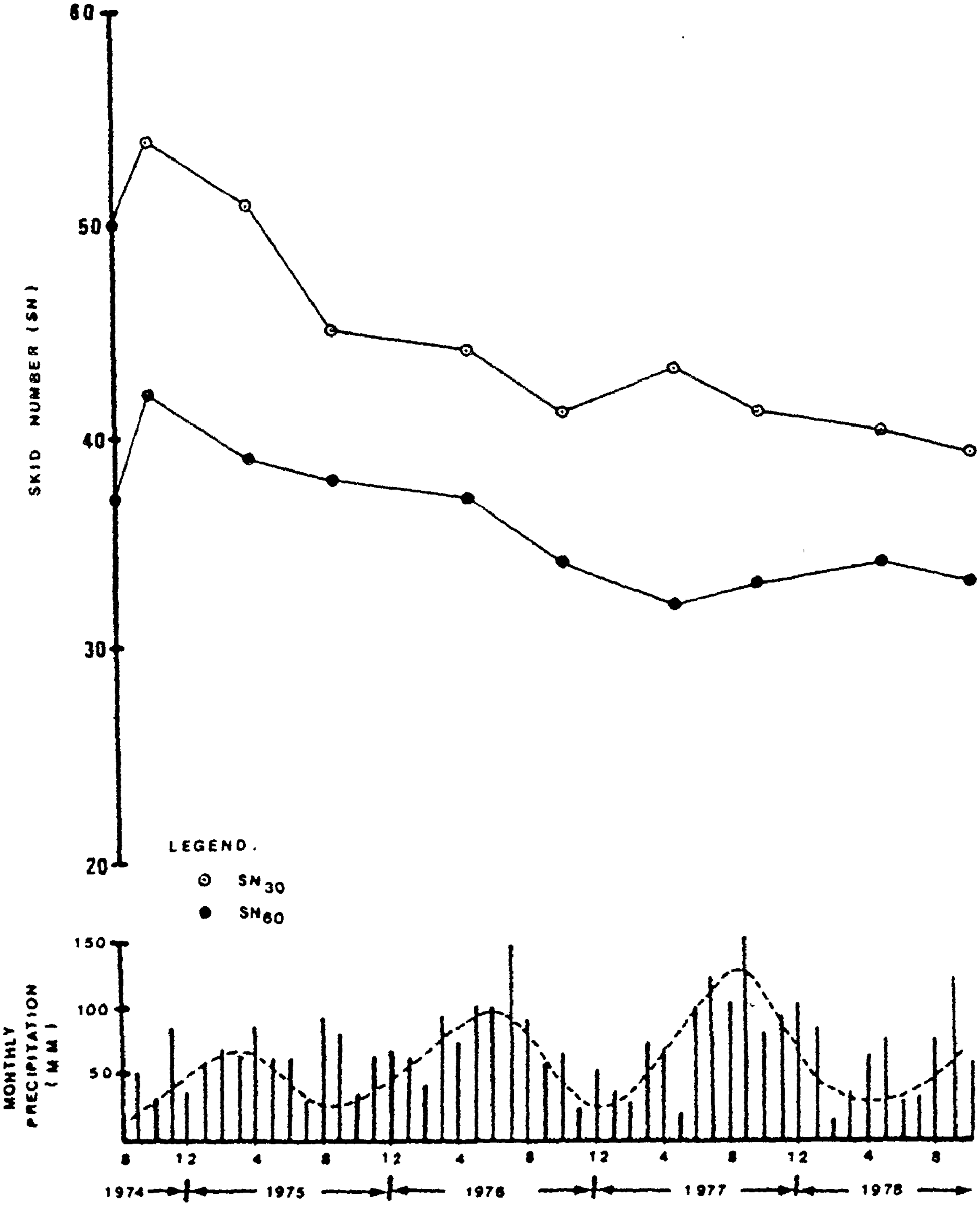


Figure 60. Skid Resistance Performance of Highway 401 Test Section No. 9 (Blast Furnace Slag), Driving Lane

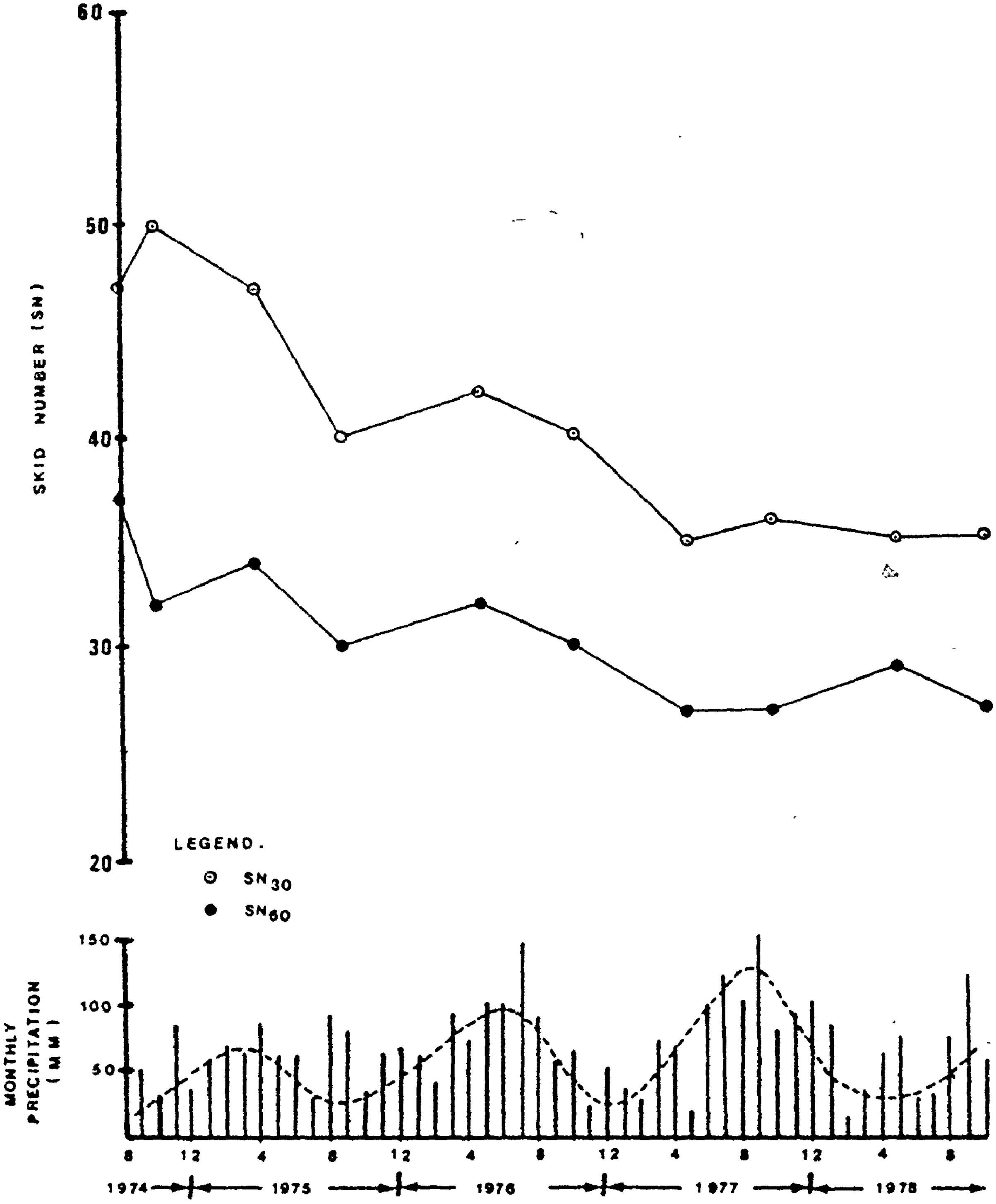


Figure 61. Skid Resistance Performance of Highway 401 Test Section No. 16 (Open Graded - Traprock), Driving Lane

aggregate. Figure 59 refers to the Test Section 8, which involved Stelco steel slag aggregate . Figure 60 refers to Test Section 9, which involved blast furnace slag aggregate . Finally, Figure 61 refers to an open graded mix design involving traprock aggregate . From Figures 58 to 61, observations can be made as follows:

1. While the skid number reading tended to decrease over the 4-year observation period, the skid numbers also showed a variation during the spring. The decreasing trend in the skid numbers is due to compaction of the pavement, polishing and abrasion. However, if at any time, the skid number is the same or higher than a previous one, it shows that there is some other process acting which has a tendency to increase the skid number. Seasonal variations in skid resistance are occurring for the test sections and weathering is clearly involved.
2. In all cases, the seasonal variations are observed more clearly during the first two years. After that time, the variation becomes smaller, although it is still observable.
3. Seasonal variations are observed for both the SN_{30} and SN_{60} readings.

4. Figures 58 and 59 show more seasonal variations than Figures 60 and 61, which shows the following:
    a. Traprock and steel slag show more seasonal variations than the test sections which were made of blast furnace slag, because the high rate of abrasion of blast furnace slag may reduce the seasonal variations (9).
    b. The seasonal variations for an open-graded mix design (Test Sections 13 to 16) are smaller than for the HL1 or modified HL1 mix design (Test Sections 1 to 11). Both Figures 58 and 61 involve traprock as the coarse aggregates; however, Figure 58 refers to an HL1 mix design while Figure 61 refers to an open-graded mix design.
5. The effect of precipitation and related factors such as anti-icing chemicals on the seasonal variations in skid resistance can be observed for the first two years. During this time, there is some relationship between precipitation and skid number readings. Higher SN readings are observed on the high cycle of the precipitation data. However, between 1977 and 1978, there is little correlation between the precipitation and the skid number readings. This may be due to the compaction process slowing, and the process of polishing and weathering starting to play important roles. This concept is presented in Figure 62.

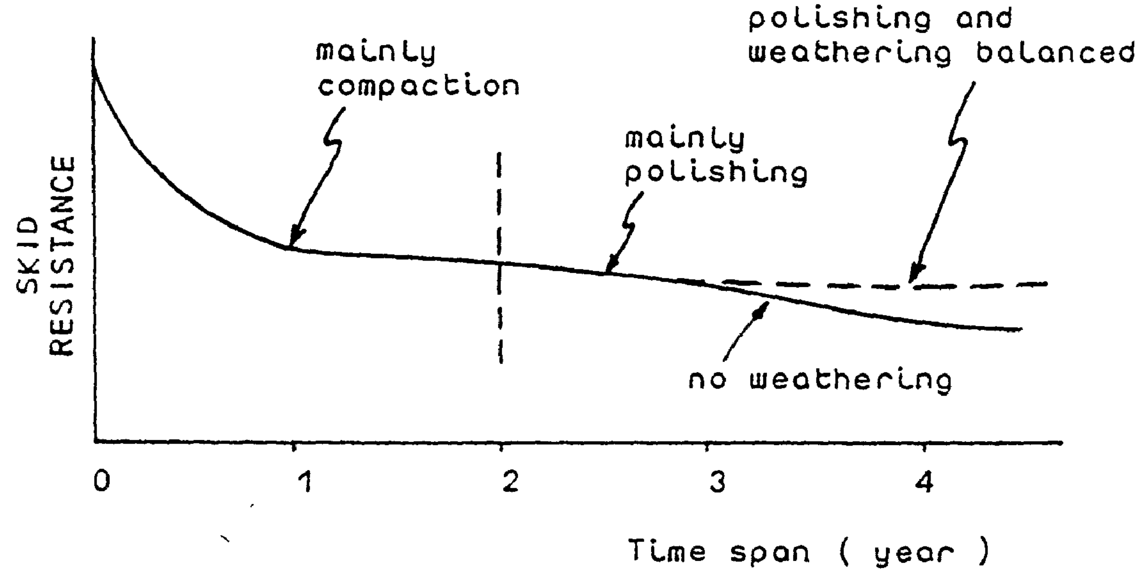


Figure 62. Model of Skid Resistance Performance of a Pavement

The mechanisms which have a tendency to increase the skid number are not well known. Some mechanisms which may effect the skid resistance performance are: weathering, differential wear, the action of sands and salt during winter seasons, etc. The dominant mechanism is not known, therefore the study of weathering effects on skid resistance is one approach to resolving this issue.

6 LABORATORY STUDY OF WEATHERING EFFECTS ON SKID RESISTANCE

6.1 SIMULATED WEATHERING

In the previous chapter, it was shown that seasonal variations in skid resistance have been observed in various studies, including this study. However, aside from observations of seasonal variations in the field, there has been little research on the influence of weathering in determining these variations. Most of the studies indicate that some factors which influence the seasonal variations might be the weathering process (17), the process of scouring the surface by sand or salt during winter season (24), the removal of oily traffic films off the road during rainy seasons (17), and many others. There has been no detailed study concentrated in this area. Therefore, there is a need to study the weathering effect on skid resistance to determine its importance and magnitude.

For this purpose, a simulated weathering process was developed in the laboratory. The aggregate was polished to simulate the traffic action and then submerged into various solutions which represent the seasonal effect on the road surface. This approach has an advantage over direct observation on the road, since the weathering process can be controlled more effectively. Other factors which add to the complexity of the problem are then eliminated, so that effects of weathering alone can be obtained.

6.2 EXPERIMENTAL PROGRAM

6.2.1 METHOD OF MEASUREMENTS

The simulated weathering process on the aggregates was monitored by changes in their Polished Stone Value (PSV). Since the weathering process is related to the change of surface texture, PSV measurements were considered suitable for this purpose. The PSV of the samples was measured using the British Portable Skid Tester (BS 812, Reference 6), which is shown in Figure 63.

By comparing the weathered PSV with the original polished-unweathered PSV, the weathering effects on skid resistance can be evaluated.

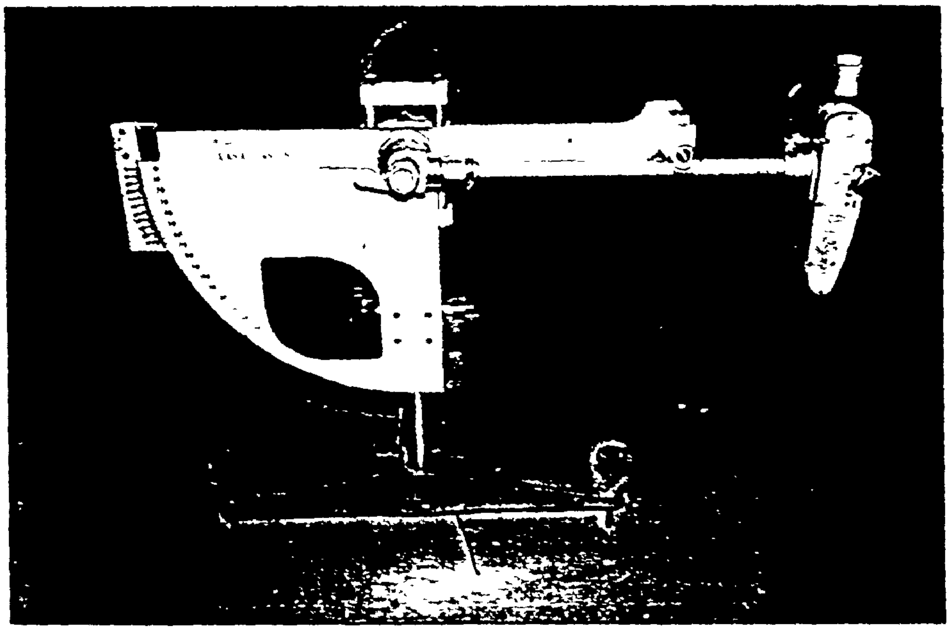


Figure 63. A British Portable Skid Tester

Basically, three types of measurement were involved:

1. PSV measurements on the original polished-unweathered aggregates. The samples were polished using a British Polishing Machine, shown in Figure 64. The procedure of polishing and PSV measurement were completed in accordance with BS 182 (6).

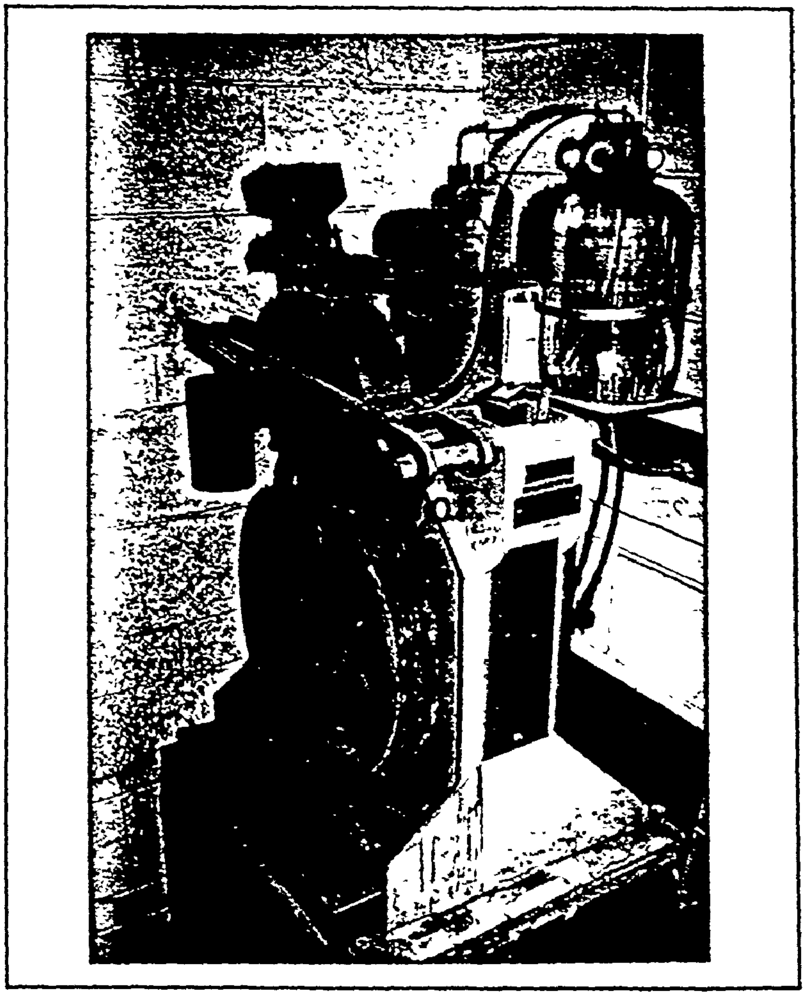


Figure 64. A British Polishing Machine

2. PSV measurements for the same samples after each series of simulated weathering. No polishing was done in this stage.
3. PSV measurements for the samples after being repolished. The degree of repolishing depended on the condition of weathering on the aggregate. This was done prior to the beginning of weathering in a different phase of the study.

6.2.2 SAMPLE PREPARATION

The tests were prepared in accordance with BS 812: 1975(6). There were four types of aggregate used in the test specimens:

a. traprock;

b. limestone (Canada Crushed Dundas Quarry);

c. Dofasco steel slag; and

d. air-cooled blast furnace slag.

Four test coupons for each type of aggregate were required to establish its PSV. In the experimental program, four types of weathering process were considered. Therefore, for the four aggregates, 64 coupons were required, plus 18 Enderby stone test coupons for control.

The four types of aggregate were submerged in four types of solution to simulate the weathering effect on the road surface. To avoid contamination and interaction among the various aggregates, separate containers were used for each type of the test coupons. The types, descriptions and/or preparations of the solution used in the weathering process were described in Chapter 3, Section 6.2. In addition to those four solutions, a part of the study also considered the effect of a 1 percent by weight NaCl solution (rock salt), instead of the $CaCl_2$ solution.

6.2.3 EXPERIMENTAL SET UP

The 64 test coupons and 18 Enderby stone control coupons were divided into 9 sets and each set subjected to a different solution. Table 7 gives these 9 sets, the aggregate type and solution type. All of the test coupons which were subjected to the simulated weathering process in the laboratory are shown in Figure 65.

Table 7. Experimental Set Up

SET No.*	TYPE OF AGGREGATE @	TYPE OF SOLUTION +
1	LS	rainfall water
2	TR,SS	rainfall water
3	TR	synthetic rain
4	TR,SS,LS	1% by wt. $CaCl_2$ sol.
5	TR,SS,BFS	distilled water
6	BFS,SS,LS	synthetic rain
7	BFS	rainfall water
8	SS	distilled water
9	BFS	1% by wt. $CaCl_2$ sol.

Notes: * Each set consists of 4 coupons of each type of aggregate, plus 2 Enderby stone coupons

@ TR : traprock SS : steel slag
LS : limestone BFS : blast furnace slag

\+ Applied for long-term study, cyclic study (both phase 1 and 2)

6.2.4 TYPES OF WEATHERING PROCESS

There were three types of weathering included in the study:

1. Long-term weathering

   In this process, the test coupon were submerged in the solution for a period of time up to 42 days.

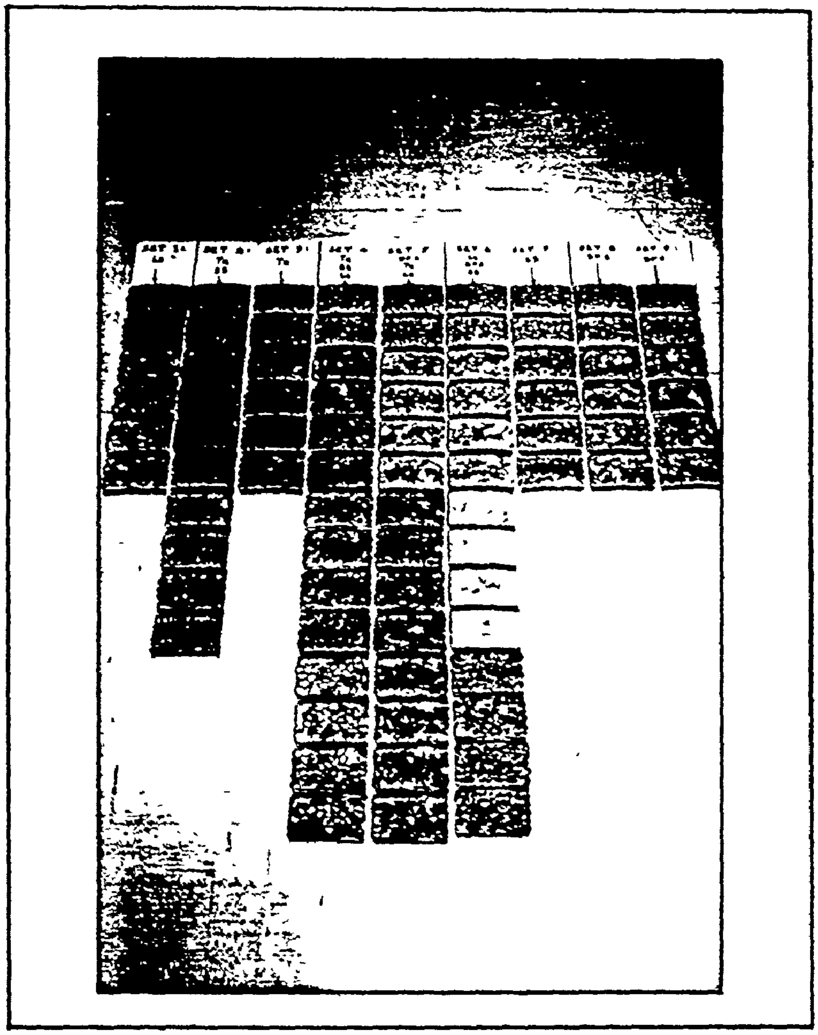


Figure 65. A Picture of Test Coupons, Grouped into 9 Sets

PSV readings were taken after the coupons had been submerged for 1, 3, 6, 10, 15, 21, 28 and 42 days in the solution.

The purpose of the long-term weathering was to study the full development of the process and its effect on skid resistance. The solution was changed after each reading.

2. Cyclic Weathering

There were two phases in this study:

a. Phase 1, in which the test coupons were subjected to wet and dry cycles as shown in Figure 66; and

b. Phase 2, in which the test coupons were subjected to wet and dry cycles as shown in Figure 67.

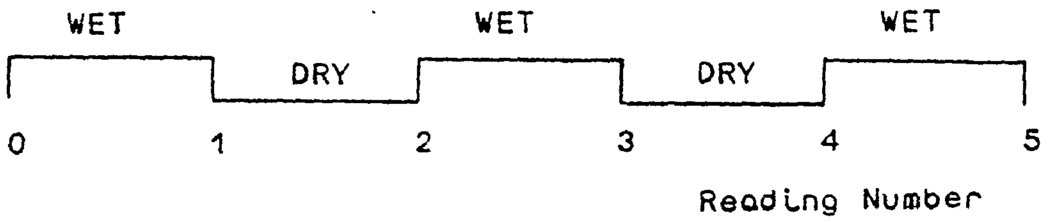


Figure 66. Cyclic Weathering : Phase 1

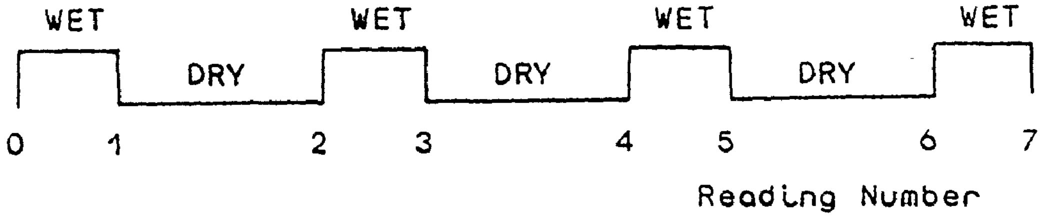


Figure 67. Cyclic Weathering : Phase 2

Both of these phases were rather short in duration (up to 10 days), since this is more representative of the actual field conditions. Furthermore, dry periods, where the coupons were dried in the air, were designed to find out if there are any changes in skid resistance after they have been previously submerged in the solution. Phase 2, a variation of Phase 1, was completed to observe if there is any changes in skid resistance performance during longer drying cycles.

3. Special Studies

The special studies were performed as an addition to the first two studies of long-term and cyclic weathering.

The studies included:

a. Weathering by 1% by weight NaCl solution. This was completed to compare the results with the tests using a $CaCl_2$ solution. Since the NaCl and $CaCl_2$ results were similar, only long-term weathering was completed for all four aggregates.

b. Short-term weathering to simulate the field weathering condition where rainfall occurs for only a short period. Due to very low increase in PSV of traprock obtained from other studies, this study concentrated on limestone, steel slag and blast furnace slag.

The study was completed using two types of solution: synthetic rain; and distilled water. It was performed up to period of 42 hours.

6.2.5 CHEMICAL ANALYSES

Apart from the simulated weathering studies, an independent study to monitor chemical interaction between the surface of the aggregates and the solutions was also completed. The overall study is explained in Appendix I.

The purpose of this part of the overall study was to examine the weathering process from a different point of view, chemical reactions, and to try to incorporate this with the simulated weathering aspects. The chemical analyses were performed using a Hach Direct Reading Kit, Model EL/2. The procedures are described in the Hach Manual (25), and it is simplified and provided in Appendix I.

6.3 INITIAL PSV MEASUREMENTS

The initial PSV of each aggregate tested is given in Table 8. Except for the Dofasco steel slag, the other aggregates tested gave initial PSV values similar to previous results: 45 for traprock; 41 for limestone; and 54 for blast furnace slag (9). However, the PSV readings for Dofasco steel slag were low in comparison to Stelco

Table 8. Initial PSV Measurements

TYPE OF AGGREGATE	SET#	INITIAL PSV
Traprock	2	45
	3	45
	4	45
	5	45
Limestone (Canada Crush)	1	43
	4	43
	5	43
	6	42
Dofasco Steel Slag	2	51
	4	45
	6	49
	8	49
Blast Furnace Slag	5	54
	6	55
	7	53
	9	55

steel slag which previously had a PSV of 59 (9). Since the PSV's for Dofasco Steel slag in Table 8 were obtained from 4 sets of independent tests, where each of the set also involved traprock, limestone or blast furnace slag, the PSV results are definitely correct.

All four sets of Dofasco steel slag coupons were made from the same batch which was taken on March 12, 1979 from Dofasco in Hamilton, Ontario. The low value for Dofasco steel slag may be due to the composition of that particular batch. Visual examination showed that this batch contained a few smooth surface particles, which may have lowered its PSV.

In comparison to another study (9), the PSV of the limestone in Table 8 is slightly higher (2 PSV units). However, due to variations in batch and porosity, 2 PSV units are not considered significant.

6.4 LONG-TERM WEATHERING

6.4.1 TEST RESULTS

The results of the long-term weathering are shown in Figures 68 to 75. Basically, Figures 68 to 71 are similar to Figures 72 to 75 as they are just presented in a different way. All of the PSV readings which were recorded to obtain these figures are given in Appendix F. For Figures 68 to 71, each graph represents the performance of one type of aggregate under the process of weathering in four different solutions. On the other hand, to examine and compare the performance among the four aggregates,

Figure 68. Traprock Under Long-term Weathering

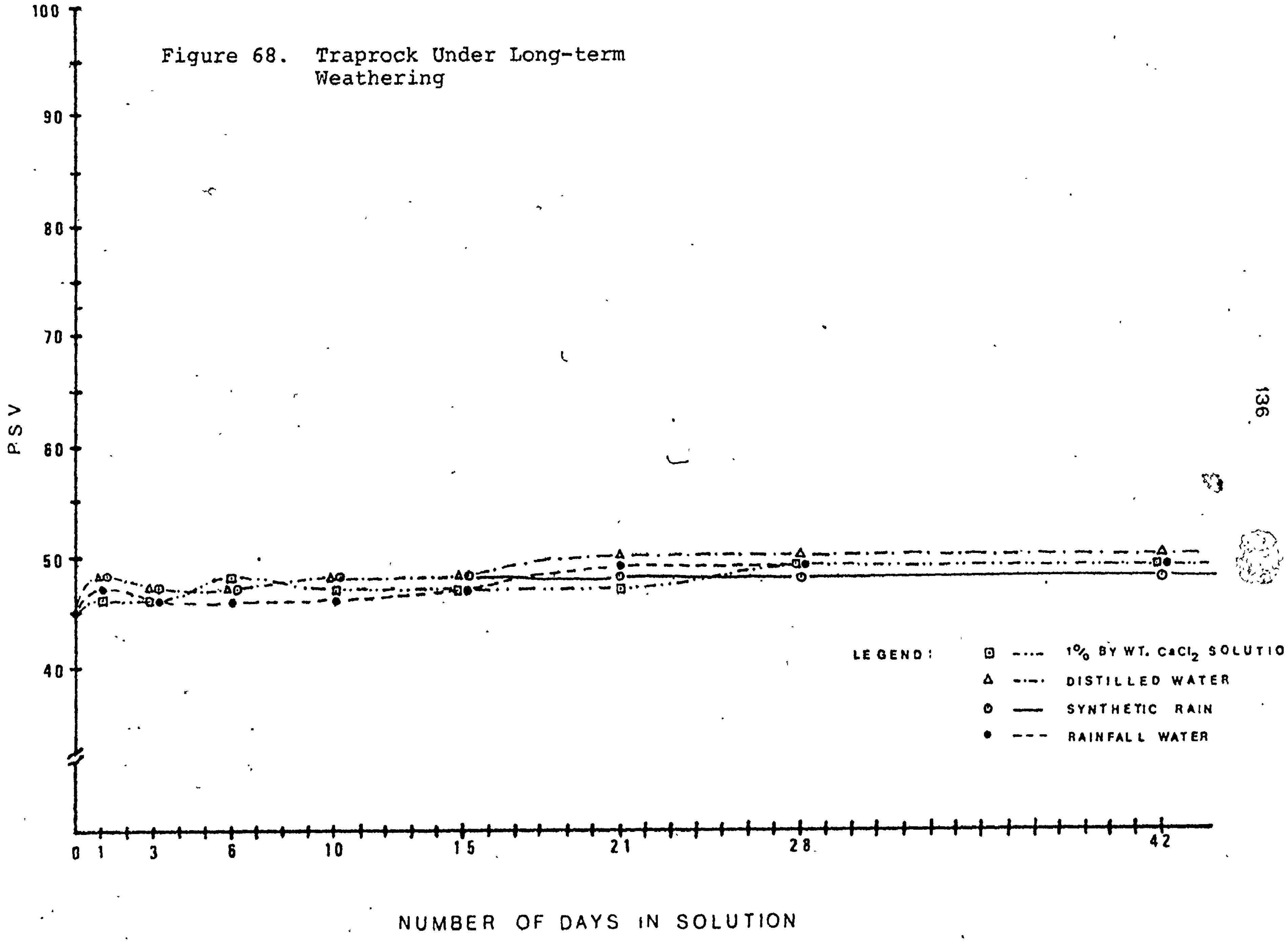
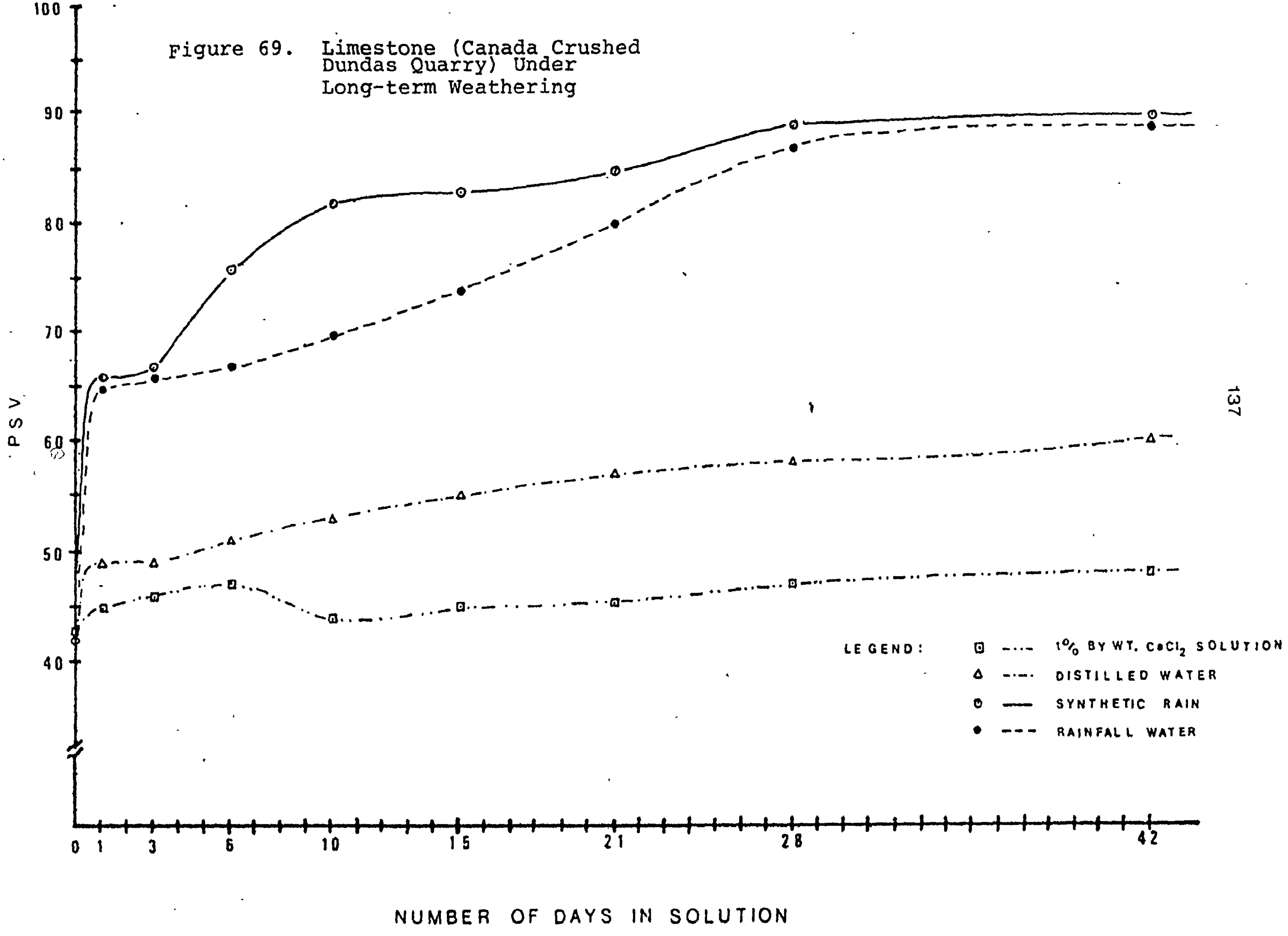


Figure 69. Limestone (Canada Crushed Dundas Quarry) Under Long-term Weathering



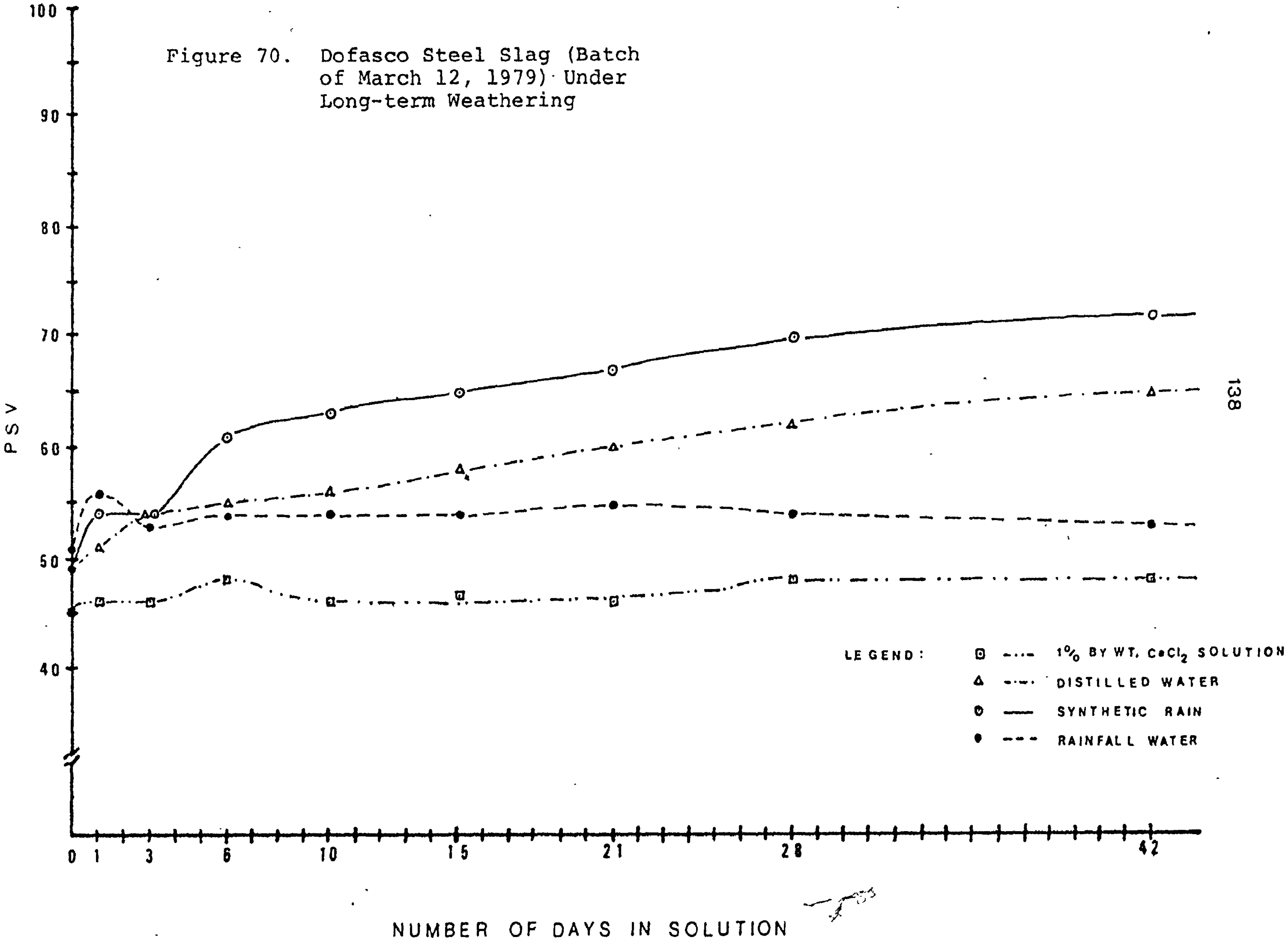
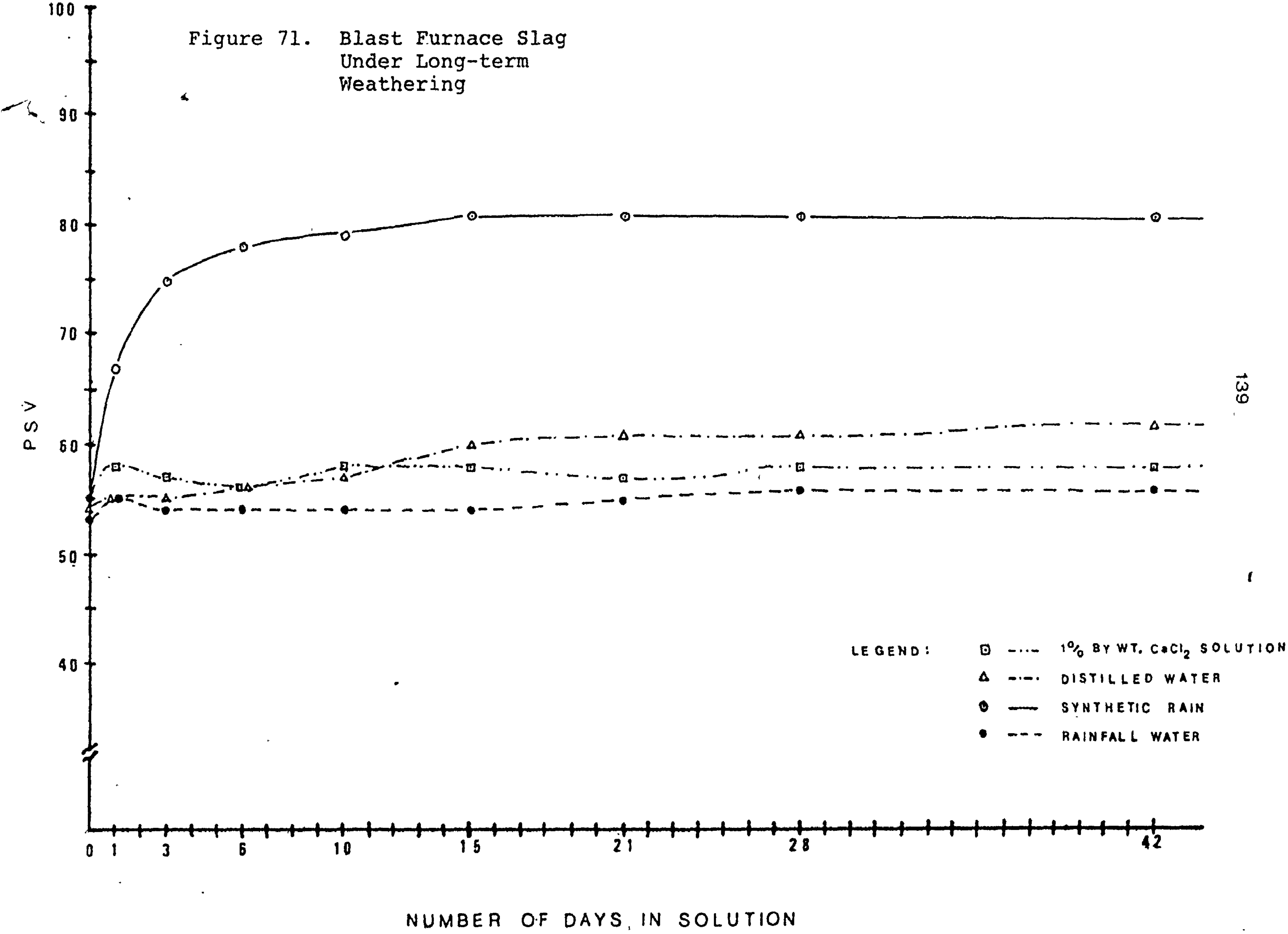


Figure 70. Dofasco Steel Slag (Batch of March 12, 1979) Under Long-term Weathering

Figure 71. Blast Furnace Slag Under Long-term Weathering



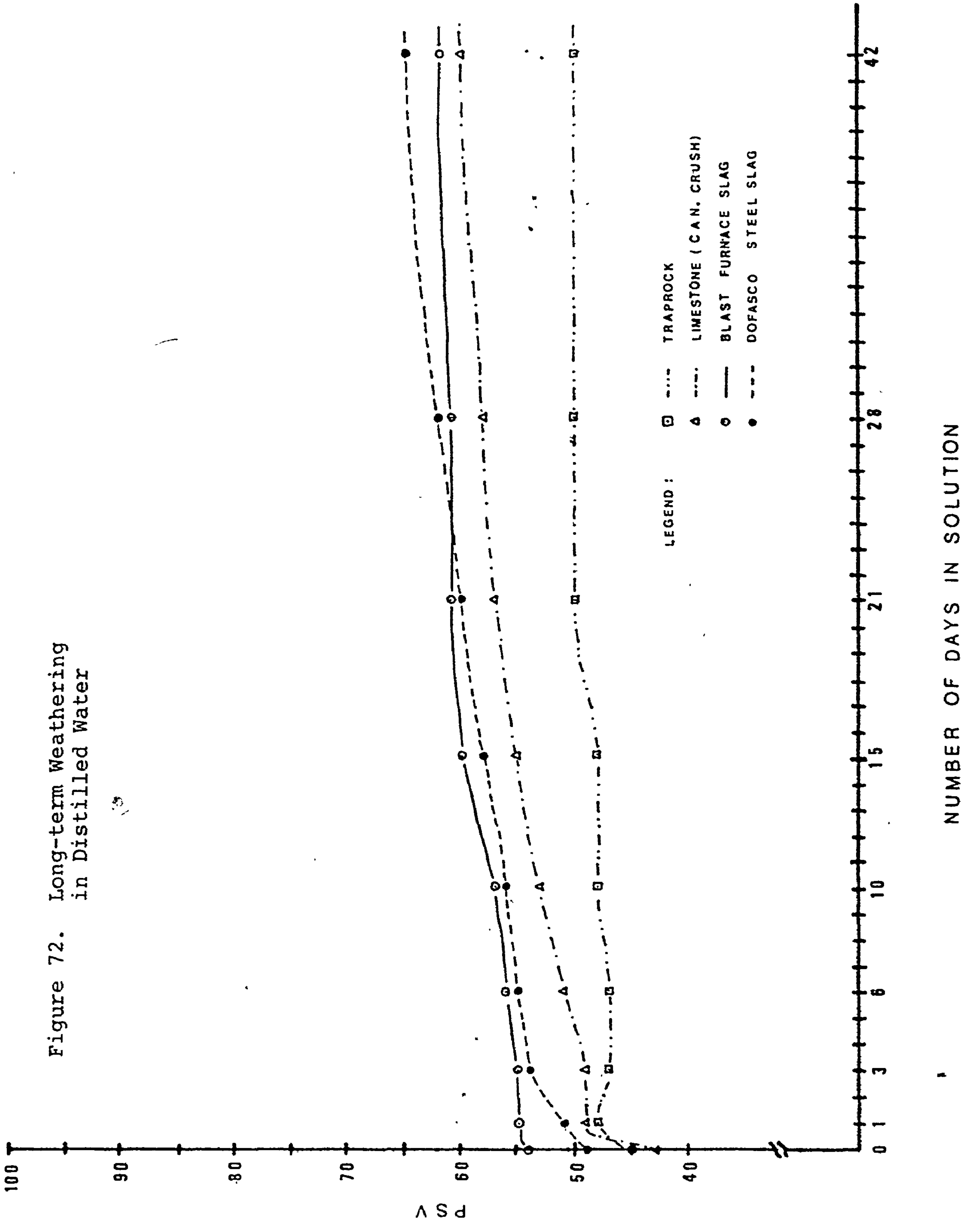


Figure 72. Long-term Weathering in Distilled Water

Figure 73. Long-term Weathering in Rainfall Water (Collected in Hamilton, Ontario on June 24th, 1979)

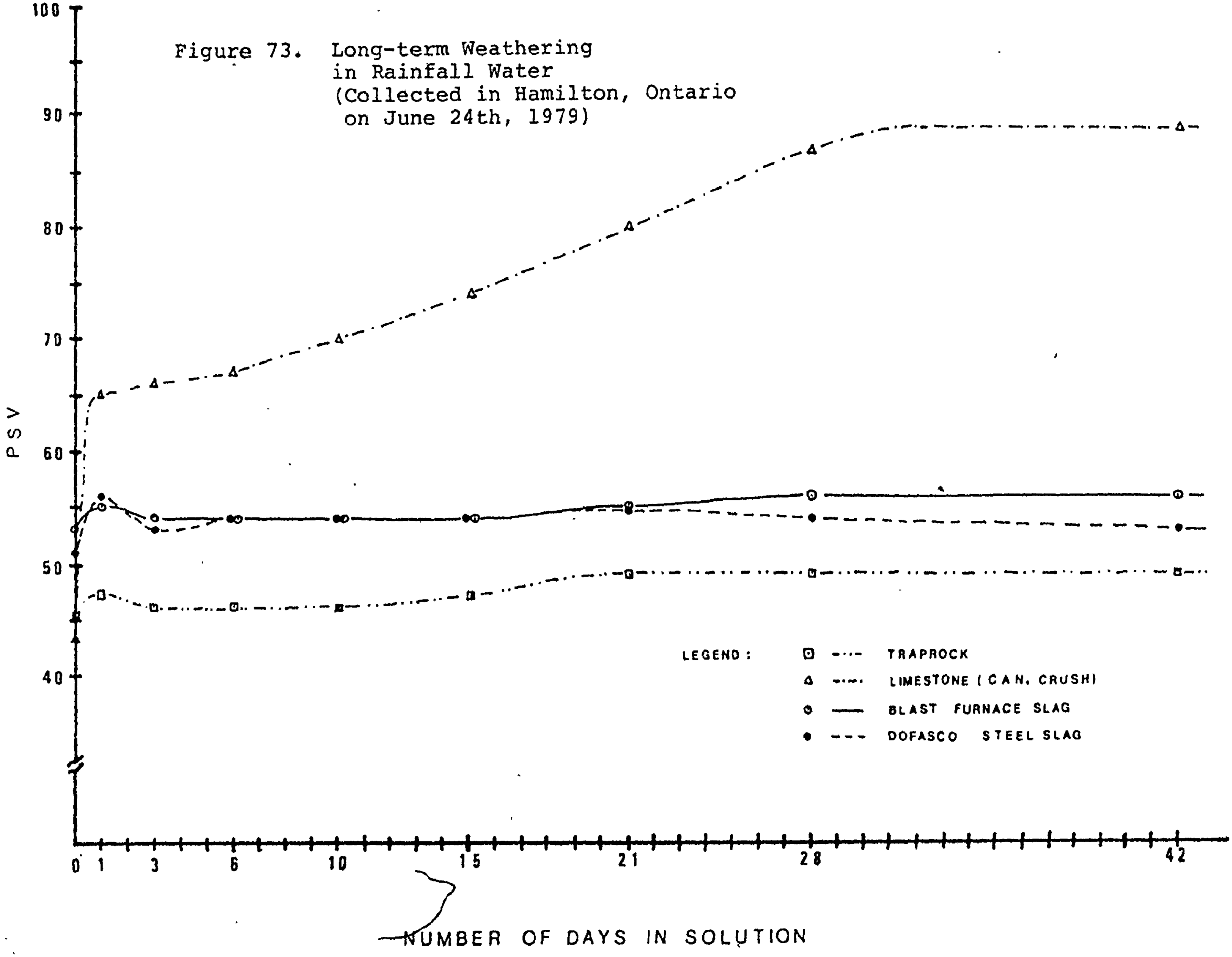


Figure 74. Long-term Weathering in Synthetic Rain (Reference 11)

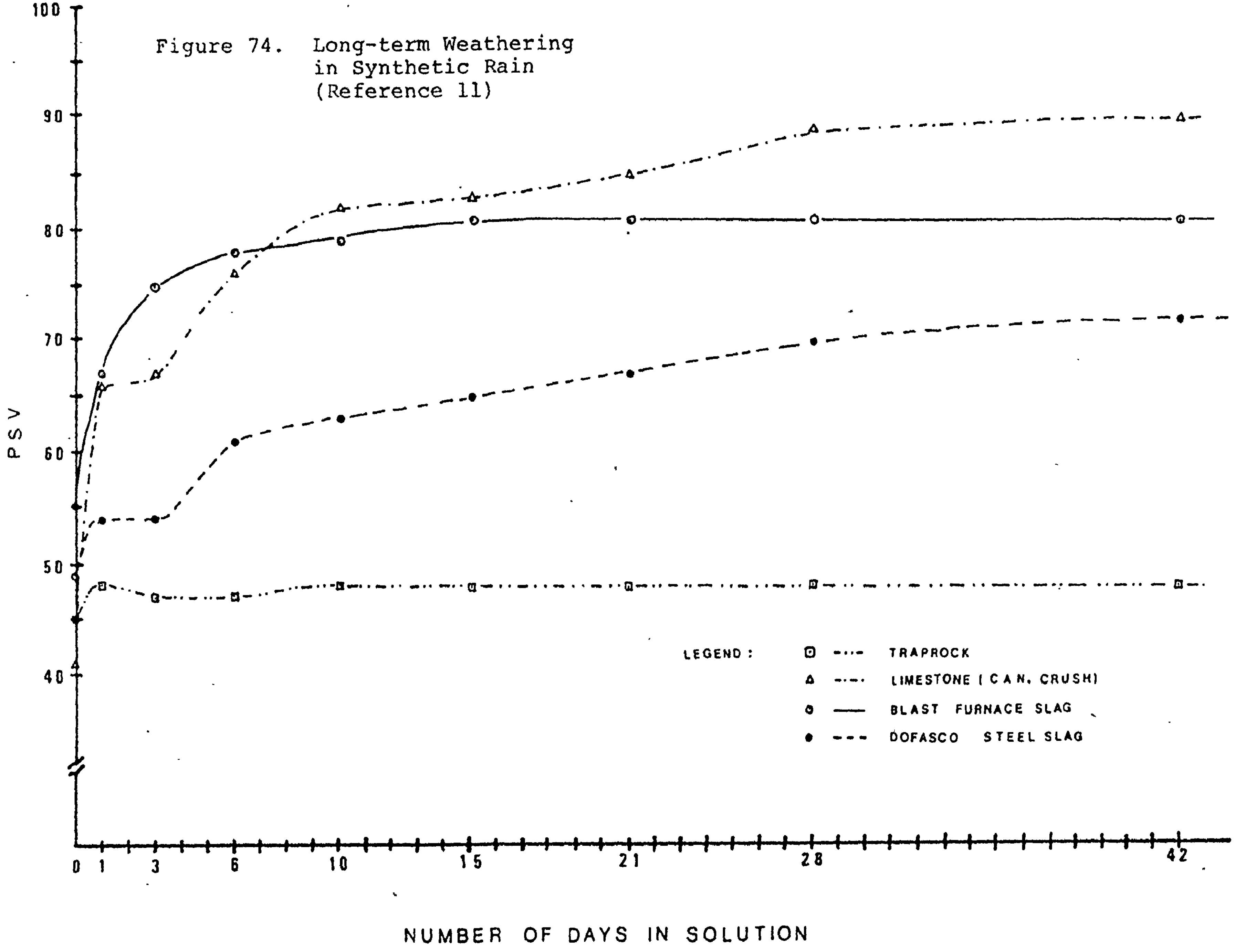
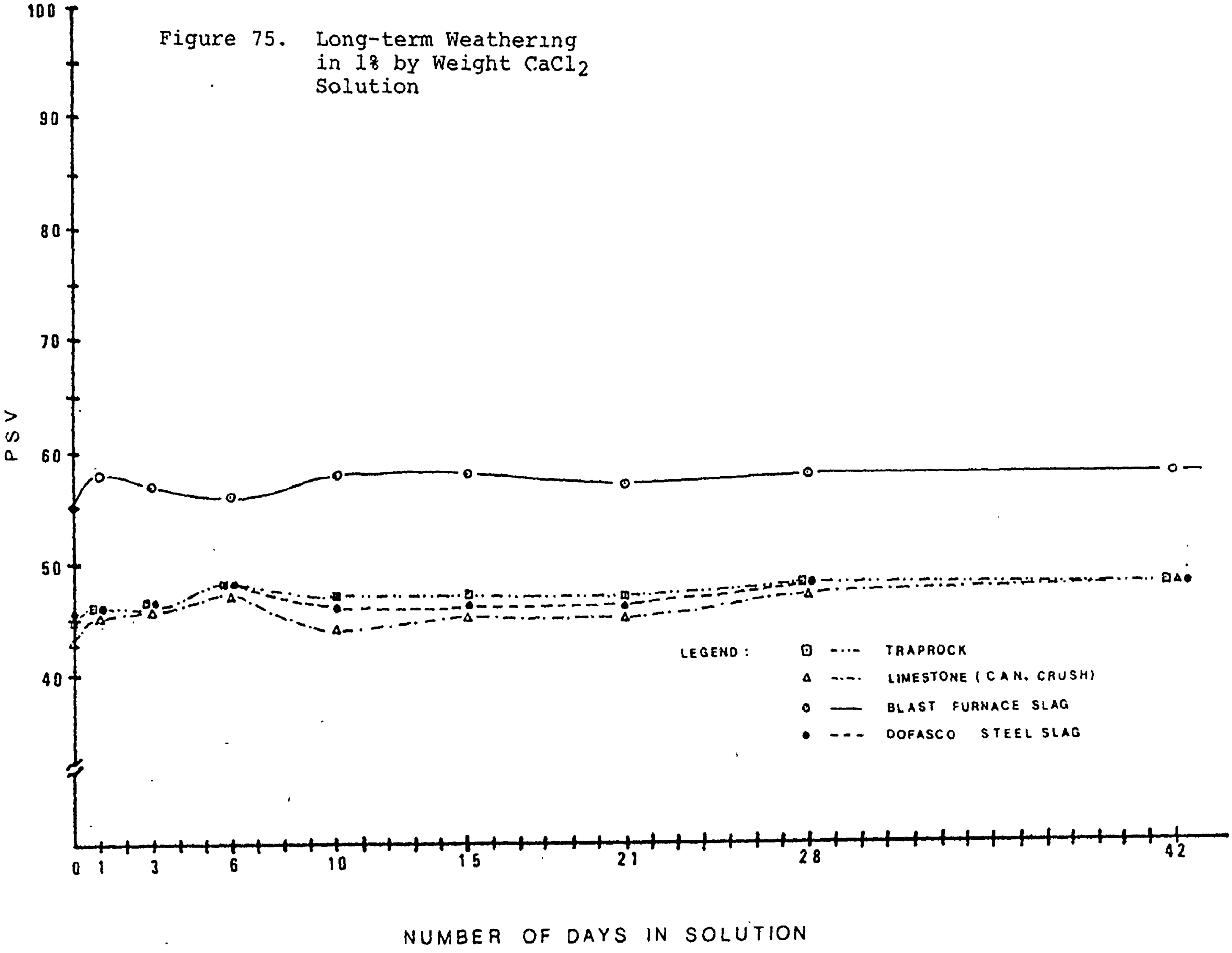


Figure 75. Long-term Weathering in 1% by Weight $CaCl_2$ Solution



Figures 72 to 75 show the PSV readings plotted against the number of days of weathering in a particular solution. Each of these figures consists of four graphs which represent four types of aggregate.

6.4.2 PERFORMANCE OF AGGREGATES UNDER LONG-TERM WEATHERING

The performance of the aggregates under the long-term weathering can be summarized as follows:

1. Traprock

   As shown in Figure 68, there was not much increase in the PSV of traprock under various solutions. It was found that after 42 days, traprock in distilled water had the greatest increase in PSV. However, this difference from the other three graphs was only about 2 PSV units. Traprock undergoes very small changes during the process of weathering, in which a summary of the tests is given in Table 9.

2. Limestone

   The skid resistance performance of limestone for various weathering solutions is shown in Figure 69. From this figure, it is clear that rainfall water and synthetic rain had the greatest effect on the PSV of limestone. Both the rainfall water and synthetic rain increased the PSV to around 90.

Table 9. Traprock Under Long-term Weathering

SET#	TYPE OF SOLUTION	INITIAL	AFTER 1 DAY		AFTER 10 DAYS		AFTER 42 DAYS	
		PSV	PSV	% increase	PSV	% increase	PSV	% increase
5	Distilled water	45	48	7	48	7	50	11
2	Rainfall water	45	47	4	47	4	49	9
3	Synthetic rain	45	48	7	48	7	48	7
4	$CaCl_2$ solution	45	46	2	47	4	48	7

Table 10. Limestone Under Long-term Weathering

SET#	TYPE OF SOLUTION	INITIAL	AFTER 1 DAY		AFTER 10 DAYS		AFTER 42 DAYS	
		PSV	PSV	% increase	PSV	% increase	PSV	% increase
5	Distilled water	43	49	14	53	23	60	40
1	Rainfall water	43	65	51	70	63	89	107
6	Synthetic rain	42	66	57	82	95	90	114
4	$CaCl_2$ solution	43	45	5	44	2	48	12

Observations during the first 21 days of the test showed that the rate of PSV increase for test coupons in rainfall water was smaller than for the coupons submerged in the synthetic rain.

A summary of the performance of limestone under weathering is given in Table 10. As shown in this table, the PSV of limestone went up as much as 114% under the synthetic rain condition. On the other hand, it only increased by 12% for the $CaCl_2$ solution. The early increase in PSV of limestone is very high in rainfall water and synthetic rain. Even on the first day, its PSV had increased by 51% in rainfall water and 57% in synthetic rain.

3. Dofasco Steel Slag

The skid resistance performance of steel slag for various weathering solutions is shown in Figure 70. A summary of this performance is also given in Table 11. As shown in the figure and table, the increase in PSV of steel slag after 42 days was highest in synthetic rain, followed by weathering in distilled water and $CaCl_2$ solution. In contrast, weathering in rainfall water only increased its PSV by 4% after 42 days, although readings at one and 10 days showed increases of higher than 4%. Because steel slag has a rather "complex" chemical nature, this may be the source of scatter in the monitoring and also explain the overall trends.

Table 11. Dofasco Steel Slag Under Long-term Weathering

SET#	TYPE OF SOLUTION	INITIAL PSV	AFTER 1 DAY		AFTER 10 DAYS		AFTER 42 DAYS	
			PSV	% increase	PSV	% increase	PSV	% increase
8	Distilled water	49	51	4	56	14	65	33
2	Rainfall water	51	56	10	54	6	53	4
6	Synthetic rain	49	54	9	63	29	72	47
4	$CaCl_2$ solution	45	46	2	46	2	48	7

Table 12. Blast Furnace Slag Under Long-term Weathering

SET#	TYPE OF SOLUTION	INITIAL PSV	AFTER 1 DAY		AFTER 10 DAYS		AFTER 42 DAYS	
			PSV	% increase	PSV	% increase	PSV	% increase
5	Distilled water	54	55	2	57	6	62	15
7	Rainfall water	53	55	4	54	2	56	6
6	Synthetic rain	55	67	22	79	44	81	47
9	$CaCl_2$ solution	55	58	5	58	5	58	5

4. Blast Furnace Slag

As indicated in Figure 71 and Table 12, blast furnace slag showed a high increase of PSV in synthetic rain weathering (47% increase after 42 days). Similar to steel slag, there was a small increase of PSV in the rainfall solution (6% increase after 42 days).

6.4.3 EFFECTS OF TYPES OF SOLUTION ON LONG-TERM WEATHERING

To compare the performance of the aggregates for the same weathering condition, it is necessary to analyze the test results for the aggregates in each type of solution. The long-term weathering study can be summarized as follows:

1. Weathering in Distilled Water

The weathering process in distilled water is summarized in Figure 72. Since the initial PSV of the four aggregates were not the same, Table 13 gives a somewhat better comparison. Limestone, followed by steel slag, showed higher increases in comparison to the performance of traprock and blast furnace slag. Although limestone had a greater percentage increase in the PSV in comparison to steel slag, Figure 72 shows that the final PSV of steel slag is still about

Table 13. Long-term Weathering in Distilled Water

SET#	TYPE OF AGGREGATE	INITIAL	AFTER 1 DAY		AFTER 10 DAYS		AFTER 42 DAYS	
		PSV	PSV	% increase	PSV	% increase	PSV	% increase
5	Traprock	45	48	7	48	7	50	11
5	Limestone (Can. Crush)	43	49	14	53	23	60	40
8	Dofasco Steel Slag	49	51	4	56	14	65	33
5	Blast Furnace Slag	54	55	2	57	6	62	15

Table 14. Long-term Weathering in Rainfall Water

SET#	TYPE OF AGGREGATE	INITIAL	AFTER 1 DAY		AFTER 10 DAYS		AFTER 42 DAYS	
		PSV	PSV	% increase	PSV	% increase	PSV	% increase
2	Traprock	45	47	4	47	4	49	9
1	Limestone (Can. Crush)	43	65	51	70	63	89	107
2	Dofasco Steel Slag	51	56	10	54	6	53	4
7	Blast Furnace Slag	53	55	4	54	2	56	6

5 PSV units higher than limestone. Therefore, steel slag still gives a better performance for weathering in distilled water, due to its higher initial PSV. Traprock showed the lowest increase of PSV for this type of weathering.

2. Weathering in Rainfall Water

The performance of the four aggregates during weathering in rainfall water is summarized in Figure 73 and Table 14. Limestone had a very high increase of PSV (107% increase in 42 days). On the other hand, the increase in PSV for steel slag, blast furnace slag and traprock were very small. After 42 days, the PSV of traprock only increased by 9%, while steel slag and blast furnace slag only increased by 4% and 6%, respectively. Figure 73 also shows that the performance of steel slag was very close to that for blast furnace slag.

3. Weathering in Synthetic Rainwater

Except for traprock, the weathering process in synthetic rain resulted in a large PSV increase. As shown in Figure 74, the PSV of limestone went from 42 to 90, the PSV of steel slag from 49 to 72, and blast furnace slag from 55 to 81. From Table 15, the 114% increase in PSV for limestone was the largest among these aggregates. Steel slag and blast furnace

Table 15. Long-term Weathering in Synthetic Rainwater

SET#	TYPE OF AGGREGATE	INITIAL PSV	AFTER 1 DAY		AFTER 10 DAYS		AFTER 42 DAYS	
			PSV	% increase	PSV	% increase	PSV	% increase
3	Traprock	45	48	7	48	7	48	7
6	Limestone (Can. Crush)	42	66	57	82	95	90	114
6	Dofasco Steel Slag	49	54	9	63	29	72	47
6	Blast Furnace Slag	55	67	22	79	44	81	47

Table 16. Long-term Weathering in 1% by Weight $CaCl_2$ Solution

SET#	TYPE OF AGGREGATE	INITIAL PSV	AFTER 1 DAY		AFTER 10 DAYS		AFTER 42 DAYS	
			PSV	% increase	PSV	% increase	PSV	% increase
4	Traprock	45	46	2	47	4	48	7
4	Limestone (Can. Crush)	43	45	5	44	2	48	12
4	Dofasco Steel Slag	45	46	2	46	2	48	7
9	Blast Furnace Slag	55	58	5	58	5	58	5

slag both increased by 47%. However, since the initial PSV for the blast furnace slag was higher than for the steel slag, the blast furnace slag still has a higher PSV than steel slag after 42 days weathering.

4. Weathering in $CaCl_2$ Solution

As shown in Figure 75 and Table 16, there was a small increase in PSV for the four aggregates for the weathering process in $CaCl_2$ solution. This indicates that the $CaCl_2$ solution inhibited the PSV change of the aggregates. After 42 days, the largest increase in PSV was for limestone (12% increase). Due to the high initial PSV, blast furnace slag had a higher PSV after weathering than the other aggregates.

6.4.4 SUMMARY

Based on the results of the long-term weathering tests, some information about the weathering process can be summarized as follows:

1. The weathering process which occurred in the tests was chemical weathering. Generally, the solutions significantly effected the aggregate PSV values.
2. For the four solutions used in the test program, synthetic rain which contains some acids and other

chemicals had the greatest effect. On the other hand, the presence of $CaCl_2$ solution seemed to inhibit the increase in PSV. This indicates that there are only certain chemicals which can affect the weathering process. In this regard, the concept of chemical equilibrium is very important as the presence of each chemical disturbs the equilibrium and a process must occur to retain the equilibrium.

3. In order that the chemical reaction can occur, the chemical composition of the aggregate surface also plays an important role. In the test program, it was found that limestone was the most active aggregate in any solution condition. On the other hand, traprock was the most stable aggregate, as its PSV did not change significantly. Due to the "complex" chemical composition of steel slag and blast furnace slag, there were significant differences between weathering in rainfall water, distilled water and synthetic rain.
4. The final PSV readings for the aggregates after 42 days of weathering are summarized in Table 17. It was generally found that there is an upper bound value for the PSV to which aggregate can rejuvenate under weathering condition. This upper bound PSV is a potential value to which the surface of the aggregate

Table 17. Results of Final PSV Testing on Long-term Weathering

TYPE OF AGGREGATE	TYPE OF SOLUTION	INITIAL PSV	PSV AFTER 42 DAYS
TRAPROCK	Distilled water	45	50
	Rainfall water	45	49
	Synthetic rainwater	45	48
	1% by wt. $CaCl_2$ sol.	45	48
LIMESTONE	Distilled water	43	60
	Rainfall water	43	89
	Synthetic rainwater	42	90
	1% by wt. $CaCl_2$ sol.	43	48
DOFASCO STEEL SLAG	Distilled water	49	65
	Rainfall water	51	53
	Synthetic rainwater	49	72
	1% by wt. $CaCl_2$ sol.	45	48
BLAST FURNACE SLAG	Distilled water	54	62
	Rainfall water	53	56
	Synthetic rainwater	55	81
	1% by wt. $CaCl_2$ sol.	55	58

can be improved by weathering; and it is termed the Potential Rejuvenating Value (PRV).

6.4.5 POTENTIAL REJUVENATING VALUE (PRV)

One of the main purposes of the long-term weathering tests was to establish the behaviour of aggregates under a slow and controllable weathering process. By allowing the process to occur over a long period of time, any chemical reactions, and chemical equilibrium will be achieved by the end of the task period. Therefore, the final PSV readings establish an upper bound on PSV which the aggregates can achieve under the most extreme of weathering process.

The reactions which occur between the aggregates and the solution, whether it is distilled water, rainfall or any chemical solution, start through the contact between the surface of the aggregate and the solution. Before this contact occurs, each of the aggregate and the solution has its own chemical equilibrium stage. Therefore, the contact between the two systems disturbs the chemical equilibrium so that the aggregate and solution then become a new combined system. After a new chemical equilibrium is achieved, the reaction stops. Because the exposed aggregate surface is limited, the reaction stops once there is no more fresh contact available.

At this stage, crystallization or leaching of material from the aggregate to the solution, has occurred.

Once the process stops, it will not start again until new exposed surface is available. This can be done by polishing or wear by traffic. There are four circled PSV values in Table 17. Except for traprock, these are considered to be the upper bound values to which these aggregates can undergo chemical reactions to produce higher PSV, and they are summarized in Table 18.

Table 18. The PRV of Aggregates

TYPE OF AGGREGATE	PRV
Traprock	52
Limestone (Canada Crushed)	90
Dofasco Steel Slag	72
Blast Furnace Slag	81

As shown in that table, the PRV of traprock is 2 units higher than shown in Table 17. This is based on the findings in Section 6.6.

The PRV represents the highest potential PSV of aggregate to which they can be rejuvenated under the weathering process after being polished to a terminal PSV. In the following sections, it is shown that the PRV is independent of the initial PSV and the PRV values in Table 18 are the upper bound values.

6.5 CYCLIC WEATHERING

6.5.1 TEST RESULTS

As explained in Section 6.2.4, there were two phases in the cyclic weathering process study. The results of the First Phase Weathering are presented in Figures 76 to 79. The results of the Second Phase Weathering are presented in Figures 80 to 83. All of the PSV readings which were recorded to produce these figures are given in Appendix G.

6.5.2 CYCLIC WEATHERING - PHASE 1

The results of the first phase of cyclic weathering can be summarized as follows:

Figure 76. Traprock Under Cyclic Weathering - Phase 1

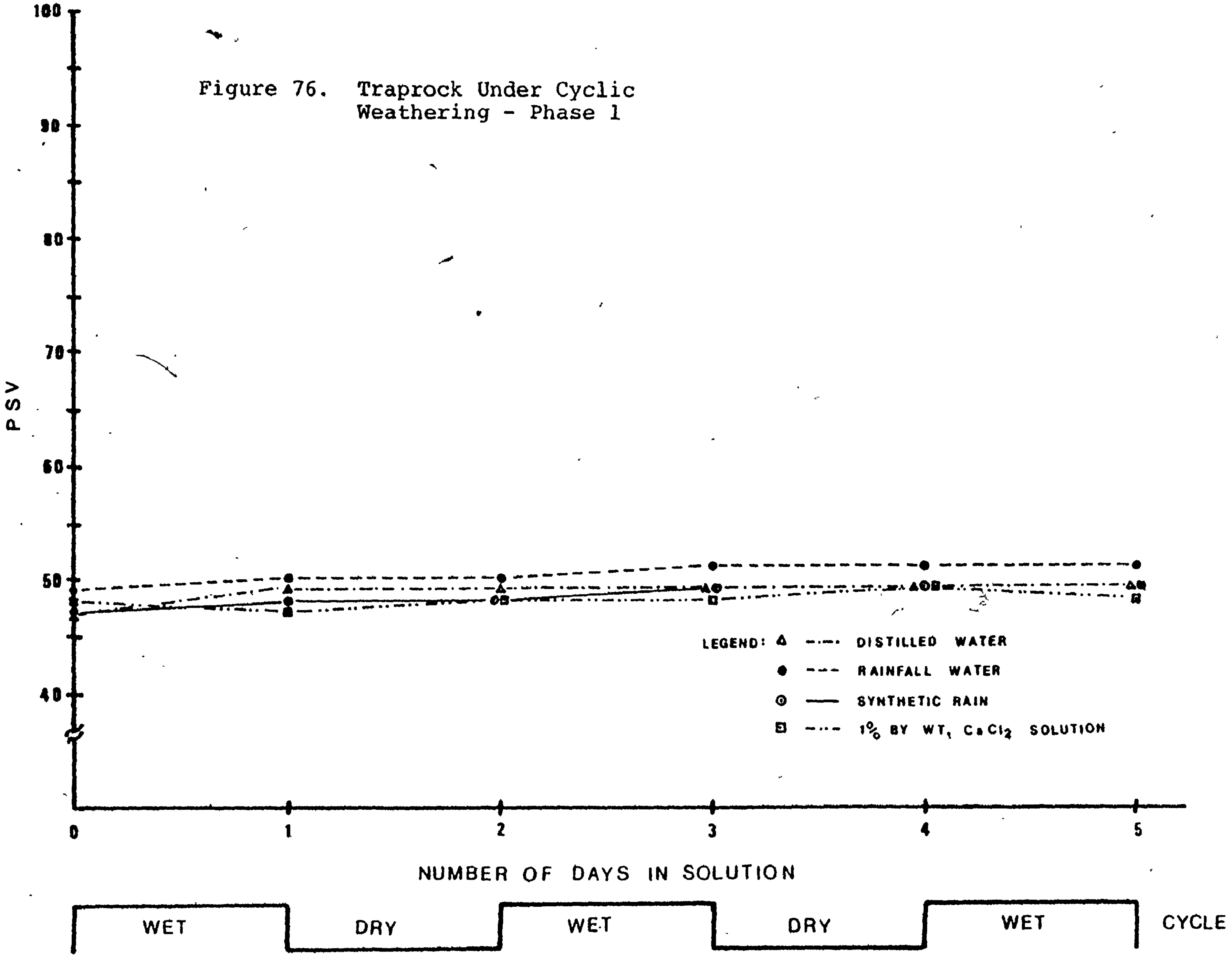


Figure 77. Limestone Under Cyclic Weathering - Phase I

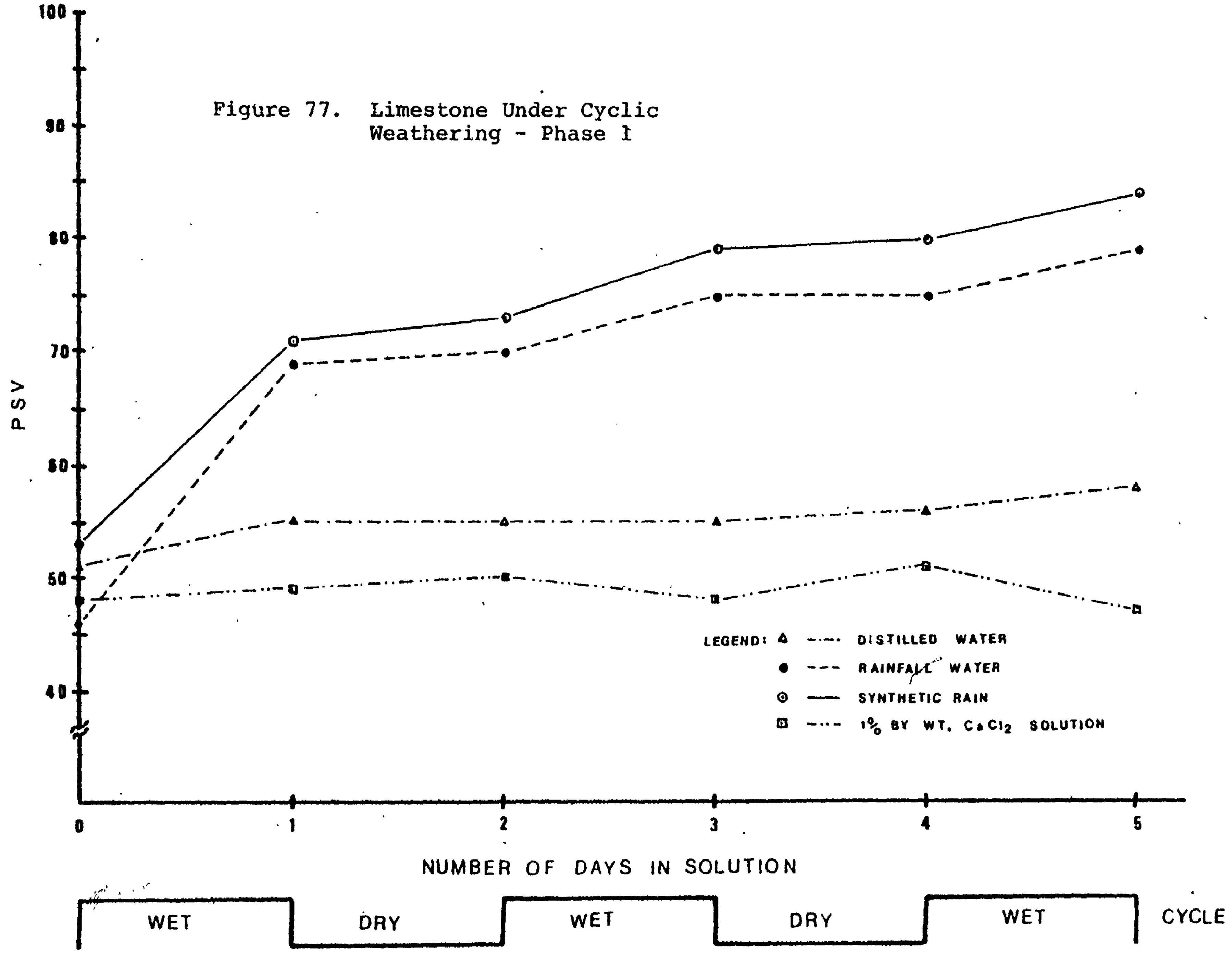


Figure 78. Dofasco Steel Slag Under Cyclic Weathering - Phase 1

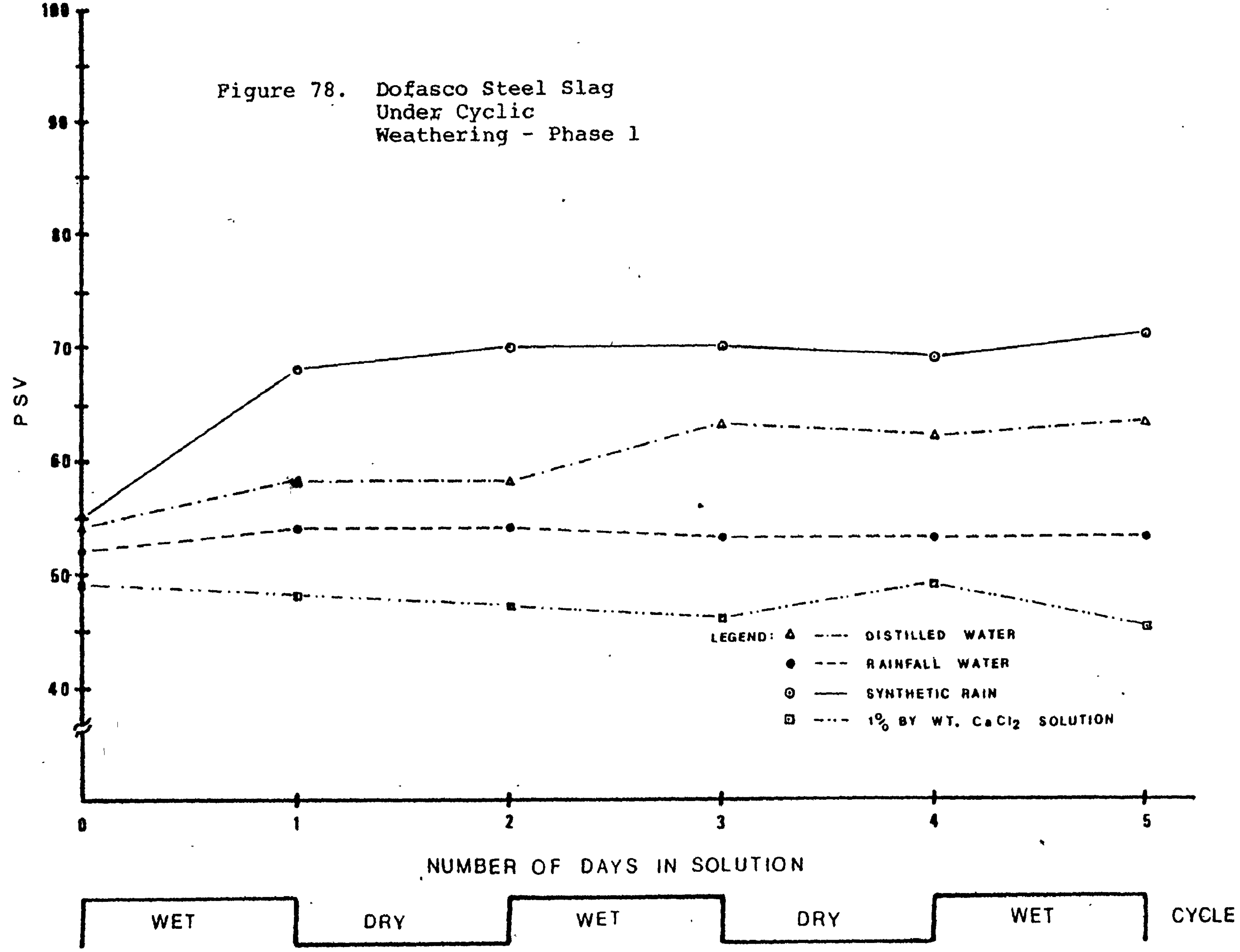


Figure 79. Blast Furnace Slag Under Cyclic Weathering - Phase 1

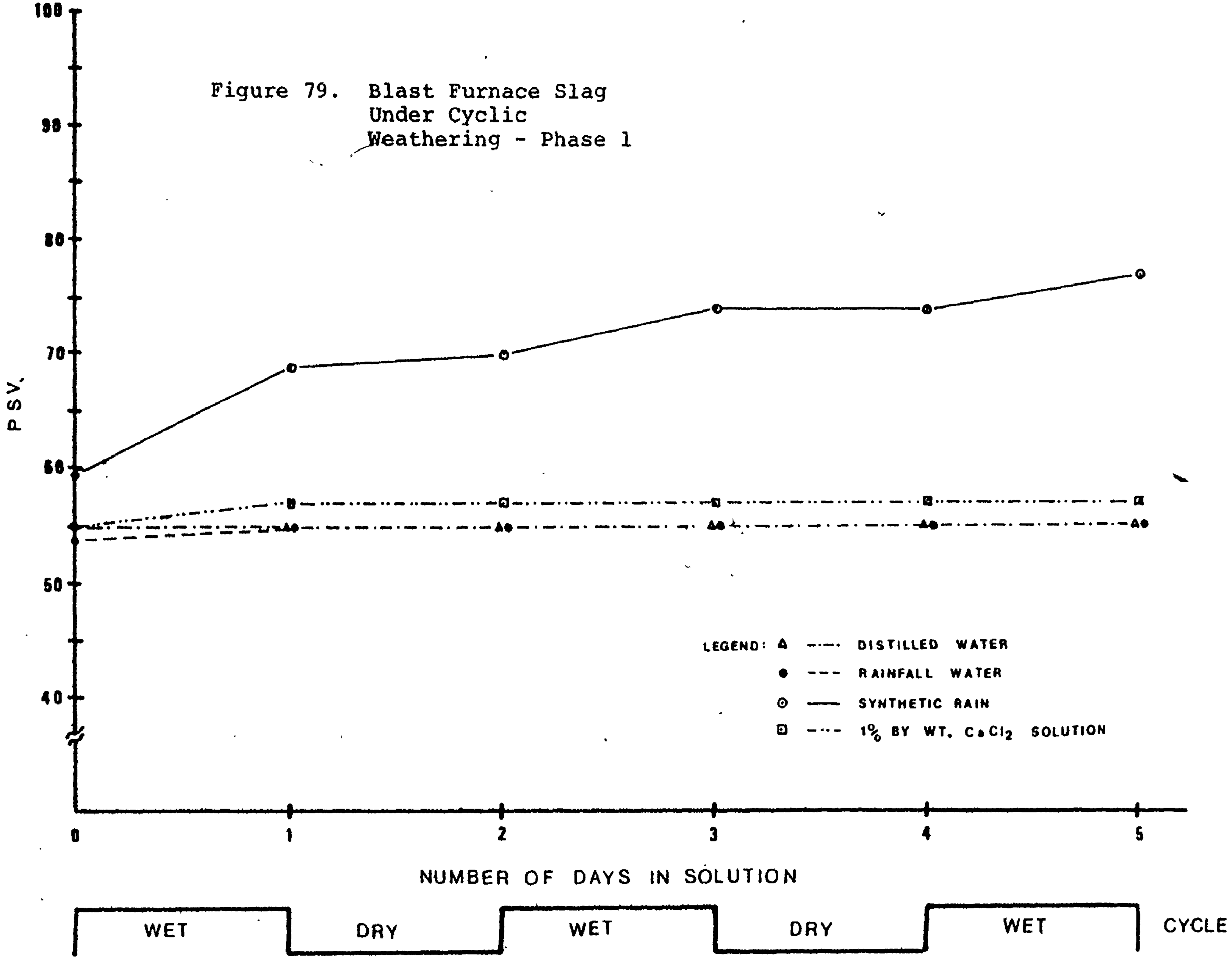
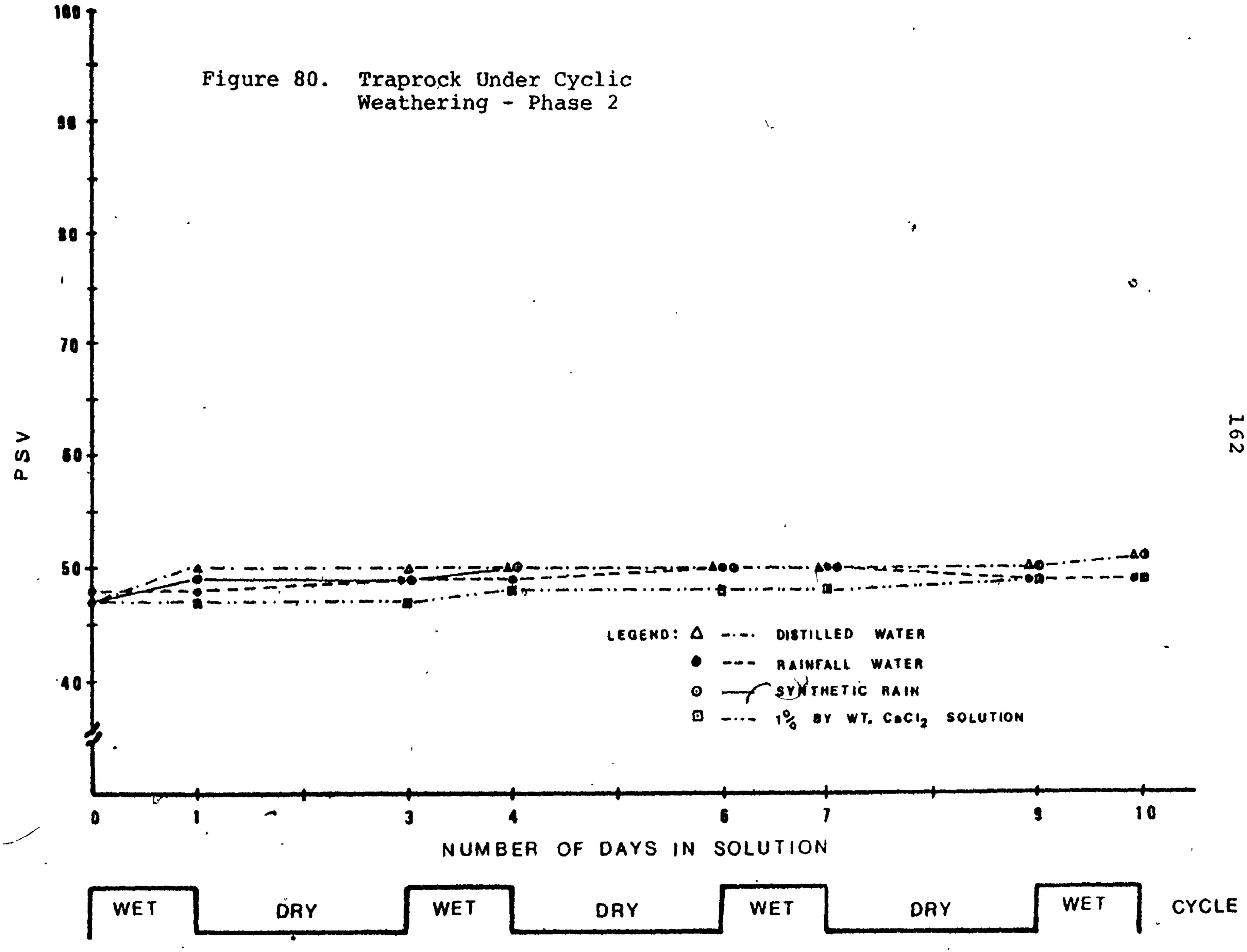


Figure 80. Traprock Under Cyclic Weathering - Phase 2



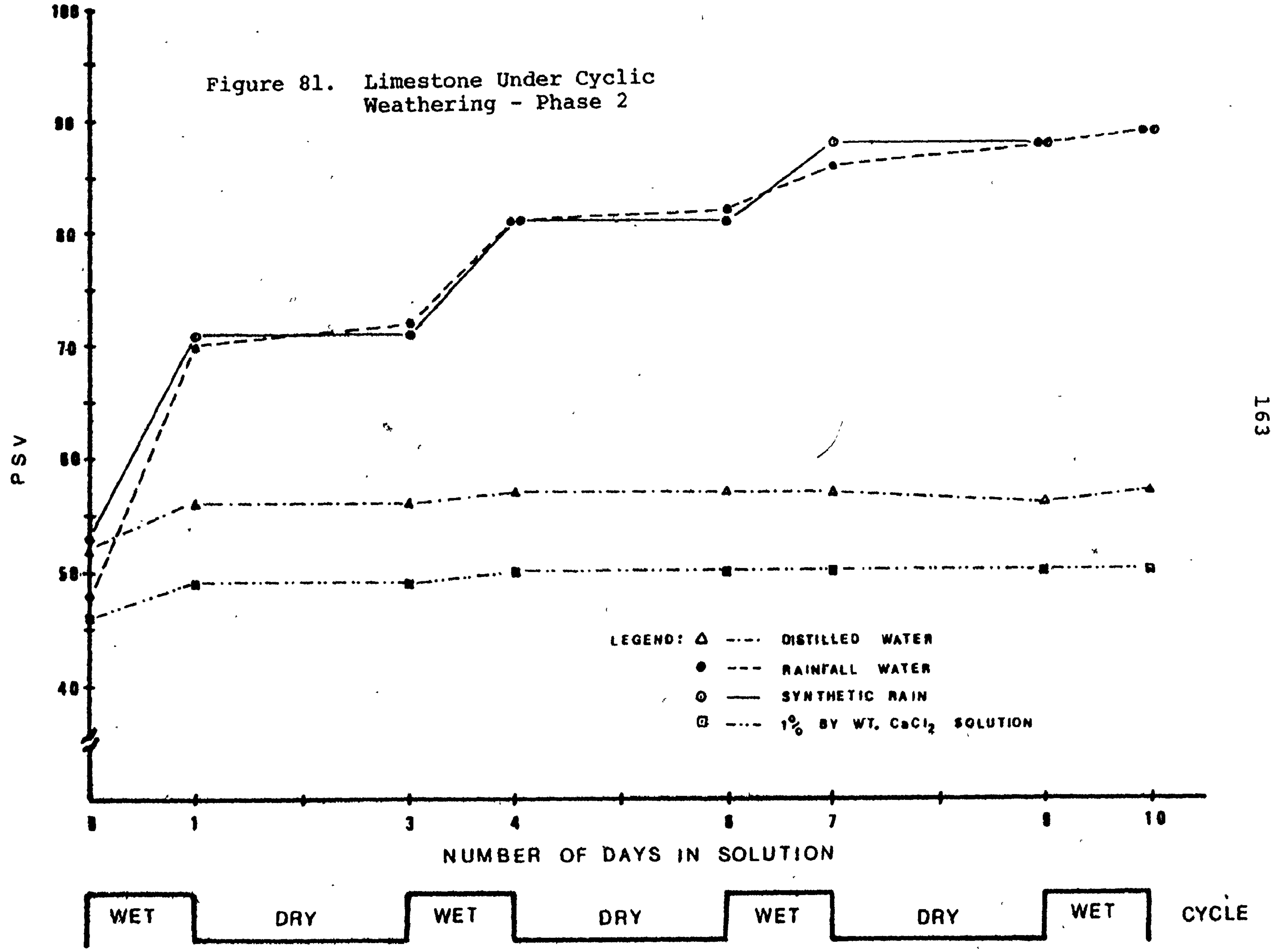
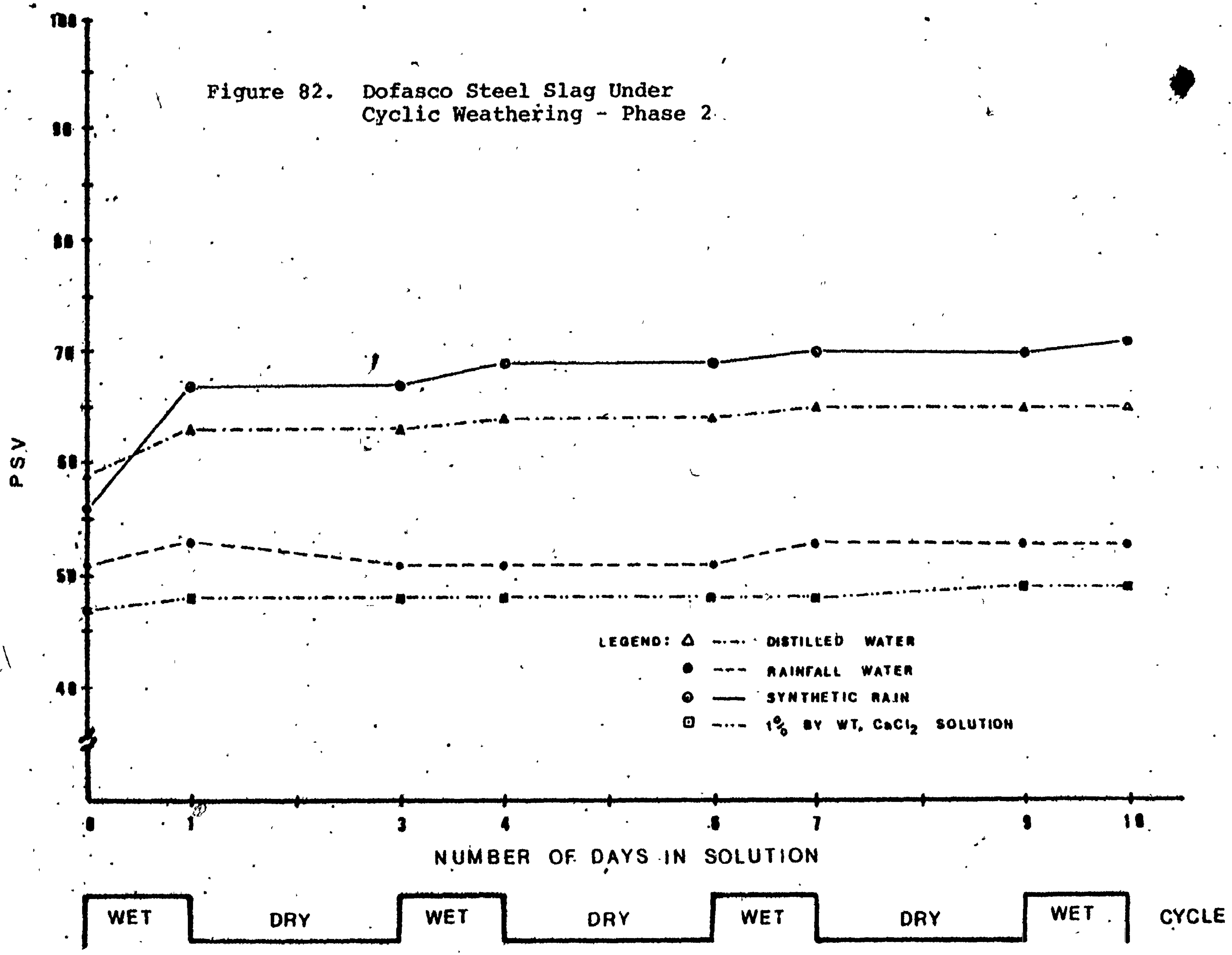


Figure 81. Limestone Under Cyclic Weathering - Phase 2

Figure 82. Dofasco Steel Slag Under Cyclic Weathering - Phase 2



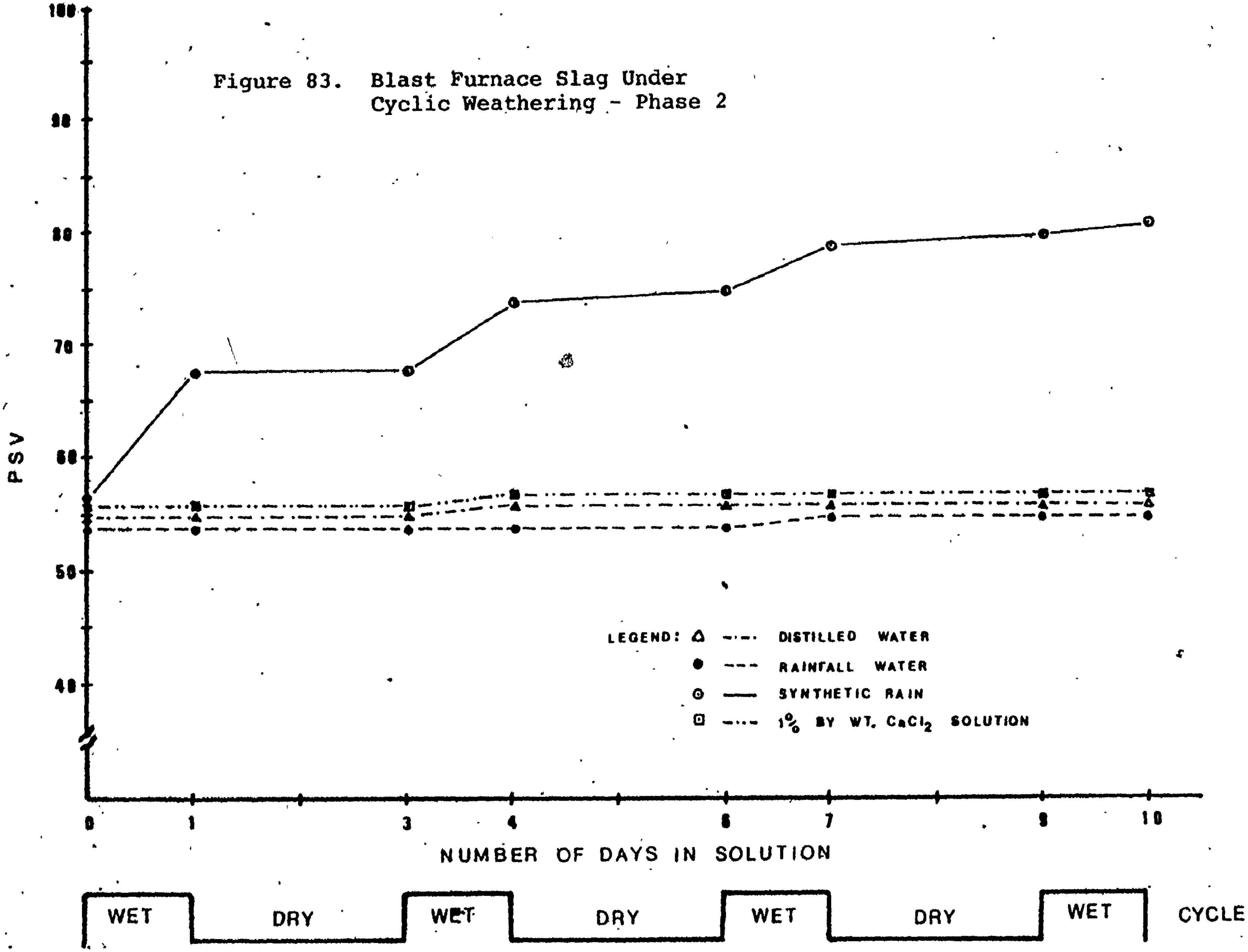


Figure 83. Blast Furnace Slag Under Cyclic Weathering - Phase 2

1. Traprock

The performance of traprock under cyclic weathering is given in Figure 76. The maximum PSV obtained at the end of the test was 51, which is less than the PRV of traprock. Except for coupons submerged in the $CaCl_2$ solution, the PSV of traprock does not change during the dry cycle. For coupons tested in $CaCl_2$ solution, the PSV fluctuates during both dry and wet cycles. This one unit of PSV variation could be caused by the hygroscopic nature of $CaCl_2$ or experimental error.

2. Limestone

The performance of limestone under cyclic weathering is given in Figure 77. This figure has some similarities with Figure 69. Both figures show that limestone in synthetic rain had the highest PSV readings, followed by tests in rainfall water and distilled water. Furthermore, the weathering in $CaCl_2$ solution did not result in increased PSV. During the dry cycles, the increase in PSV was relatively small for all solutions (increase in one or two PSV units). The highest PSV reading at the end of the test was 84, which is still less than the PRV of limestone.

3. Dofasco steel slag

The cyclic weathering process for Dofasco steel slag also shows similarities with the long-term weathering. The performance of steel slag under cyclic weathering is given in Figure 78. Similar to Figure 70, there was not much change in PSV for steel slag in rainfall water. Steel slag in distilled water and synthetic rain had a better performance than for the other two conditions. The highest PSV obtained at the end of the test was 71, which is for test coupons in synthetic rain weathering. It was also found that dry cycles produced little change in the PSV of steel slag.

4. Blast furnace slag

The performance of the blast furnace slag under cyclic weathering is given in Figure 79. There was almost no change in PSV of blast furnace slag which was in distilled water, rainfall water or $CaCl_2$ solution for cyclic weathering. However, its PSV improved significantly in synthetic rain. Similar to the other aggregates, dry cycles had very little effect on the PSV. The pattern of this figure is also similar to Figure 71 for long-term weathering of blast furnace slag.

6.5.3 CYCLIC WEATHERING - PHASE 2

In Phase 2 of the cyclic weathering study, the total test period was expanded to 10 days. There were cycles of one wet day and two dry days. The results of these tests can be summarized as follows:

1. Traprock

    The performance of traprock during the second phase of cyclic weathering is shown in Figure 80. Similar to Figures 68 and 76, all of the graphs are very flat, indicating little increase in PSV. The increase in dry cycle time did not affect the PSV readings and just delayed the weathering process. The highest PSV recorded at the end of the test was 51, which is below the PRV of traprock.

2. Limestone

    The performance of limestone during the second phase of cyclic weathering is shown in Figure 81. The highest PSV recorded at the end of the testing was 89, obtained under both rainfall water and synthetic rain conditions. This figure is also similar to Figures 69 and 77, except that in this figure, the limestone in rainfall water and in synthetic rain are very close together.

3. Dofasco Steel Slag

The performance of steel slag during the second phase of cyclic weathering, as shown in Figure 82, is similar to Figures 70 and 78. Steel slag in rainfall water still had a lower increase in PSV compared to distilled water and synthetic rain. The highest PSV obtained at the end of the test period was 71. This value, which was obtained for steel slag in synthetic rain, is lower than the PRV of steel slag.

4. Blast Furnace Slag

The results for blast furnace slag test coupons which were subjected to the second phase of cyclic weathering are shown in Figure 83. Again, this figure is similar to Figures 71 and 79. Little increase in PSV was observed for blast furnace slag in rainfall water, $CaCl_2$ solution and distilled water. However, significant changes occurred for coupons in the synthetic rain. The final PSV was 81, which is equal to the PRV of blast furnace slag. There was very little change in the PSV during the dry cycles of the test program.

6.5.4 SUMMARY

From both the first and second phases of the cyclic weathering study, some useful information about weathering influences on skid resistance can be summarized as follows:

1. The results of final PSV readings from the cyclic weathering, together with results from the long-term weathering, are given in Table 19 for comparison purposes. As shown in Table 19, the final PSV values of aggregates in both Phase 1 and Phase 2 studies are about the same or lower than the results obtained for long-term weathering. It indicates that accelerated weathering was obtained in Phase 1 and Phase 2. Comparing the long-term weathering and Phase 2, for example, it can be established that the weathering conditions accelerated the process from 42 days to 10 days. This is related to the chemical equilibrium of the system between aggregates and solutions discussed in Section 6.6.
2. The dry cycles were completed to examine any chemical reaction between the surface of the aggregate and the air after the wet cycles. The results from both the first and second phases showed that there was no further reactions occur during the dry cycles; resulting very little change in the PSV.

Table 19. Results of PSV Readings from Long-term Weathering and Cyclic Weathering

TYPE OF AGGREGATE	TYPE OF SOLUTION	Final PSV in Long-term Weathering	Final PSV in Cyclic Weathering	
			PHASE 1	PHASE 2
TRAPROCK	Distilled water	50	49	51
	Rainfall water	49	51	49
	Synthetic rainwater	48	49	51
	1% by wt. $CaCl_2$ sol.	48	48	49
LIMESTONE	Distilled water	60	58	57
	Rainfall water	89	79	89
	Synthetic rainwater	90	84	89
	1% by wt. $CaCl_2$ sol.	48	47	50
DOFASCO STEEL SLAG	Distilled water	65	63	65
	Rainfall water	53	53	53
	Synthetic rainwater	72	71	71
	1% by wt. $CaCl_2$ sol.	48	45	49
BLAST FURNACE SLAG	Distilled water	62	55	56
	Rainfall water	56	55	55
	Synthetic rainwater	81	77	81
	1% by wt. $CaCl_2$ sol.	58	57	57

3. Comparing the graphs in Figures 76 to 83, it was found that both phases of weathering have similar patterns in the development of PSV during the cyclic weathering. The graphs show rather high increases of PSV at the beginning of the wet cycles, and gradually decrease in subsequent wet cycles. These patterns also occur in long-term weathering process, in which the rates of PSV increase are decreasing with time.

6.6 SPECIAL STUDIES IN WEATHERING

6.6.1 TEST RESULTS

The special studies in weathering are intended as additional tests to gather information on the effects of weathering on skid resistance. The long-term weathering in 1% by weight NaCl solution was completed for comparison with the weathering process in $CaCl_2$. Then, the short-term weathering study was completed to develop information on the effect of time on the process. This is important, since the short-term condition is more closely related to the actual field conditions. The test results are presented in Figures 84 to 87. Detailed information with regard to test data is given in Appendix H.

Figure 84. Long-term Weathering in 1% by Weight NaCl Solution

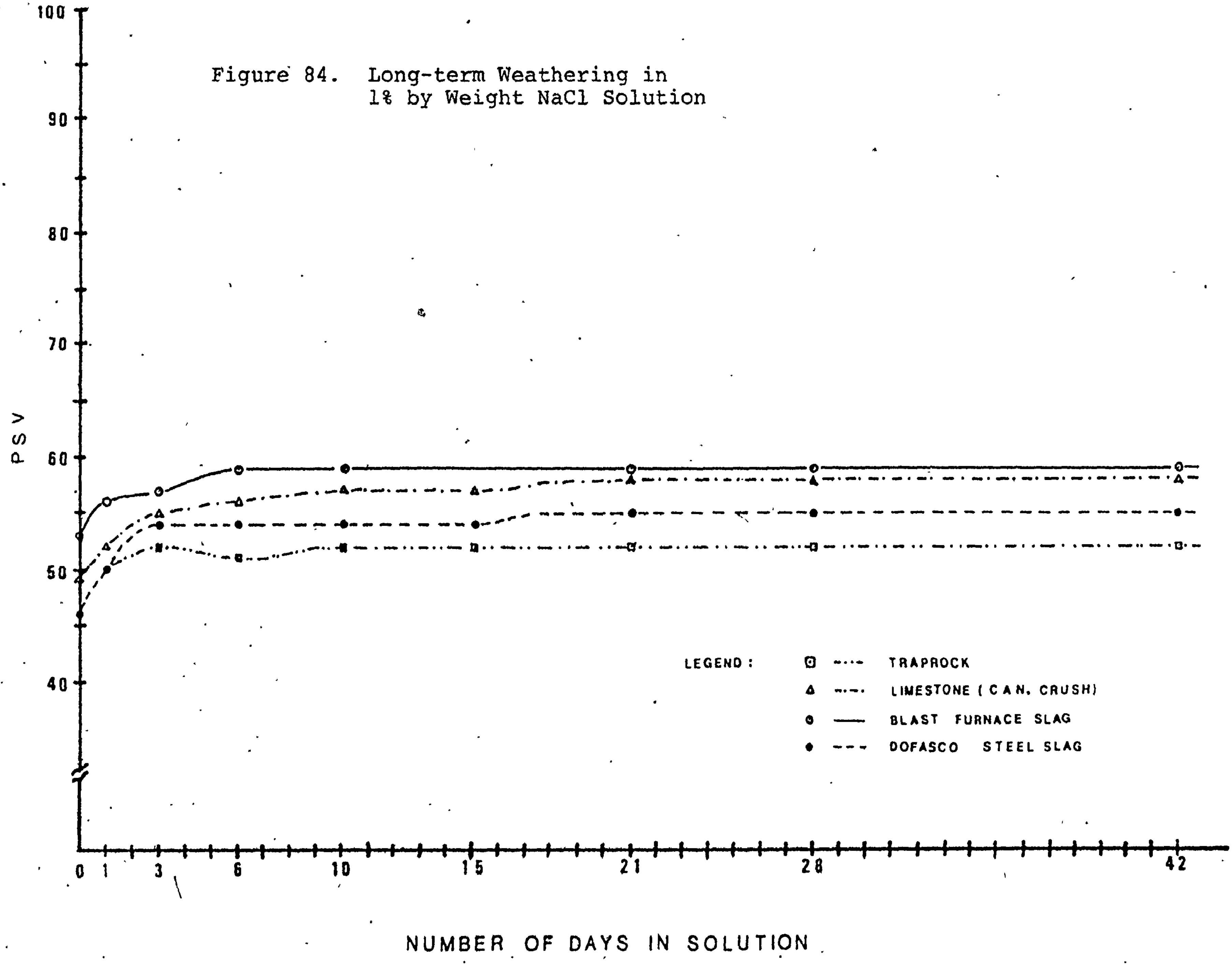


Figure 85. Limestone Under Short-term Weathering

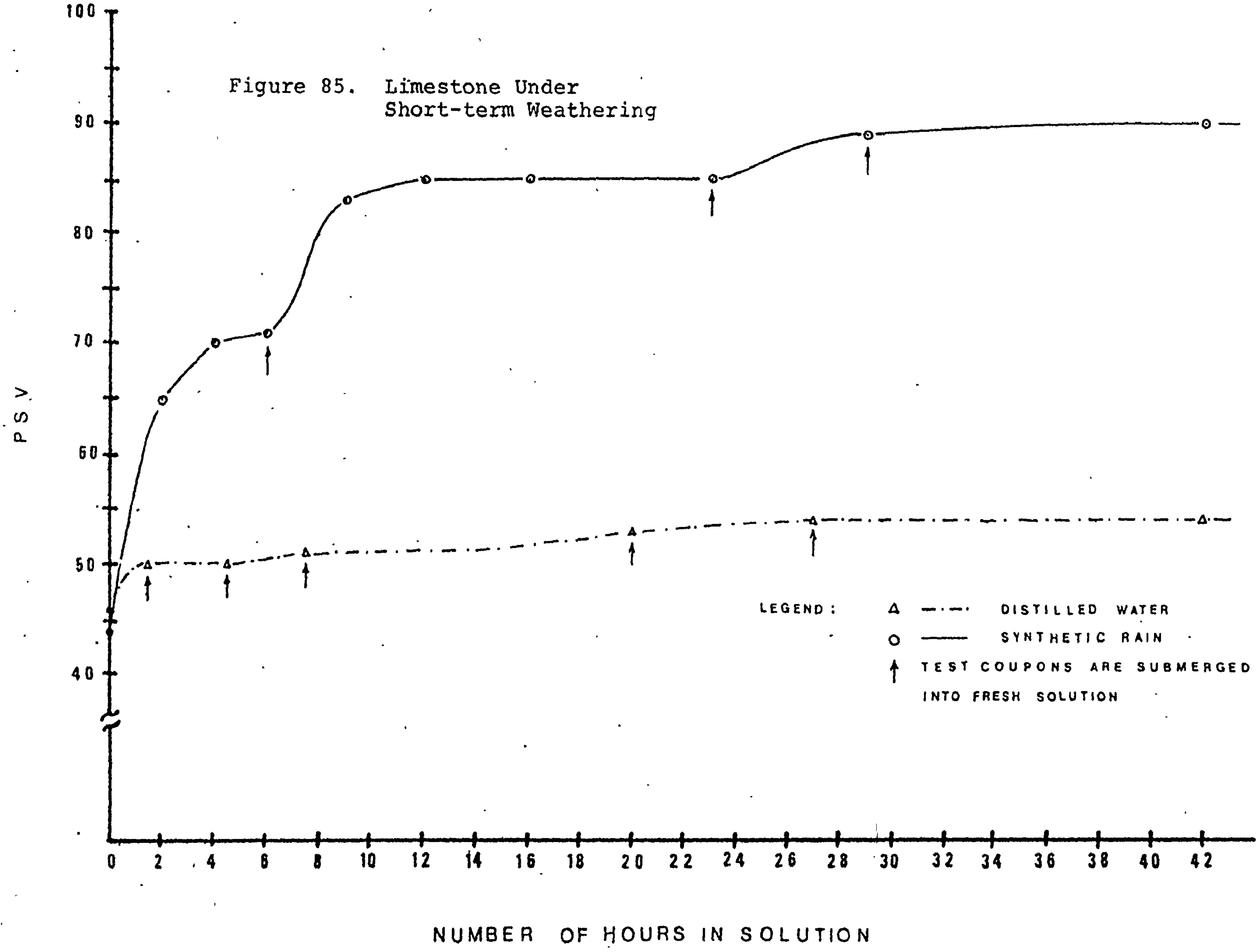
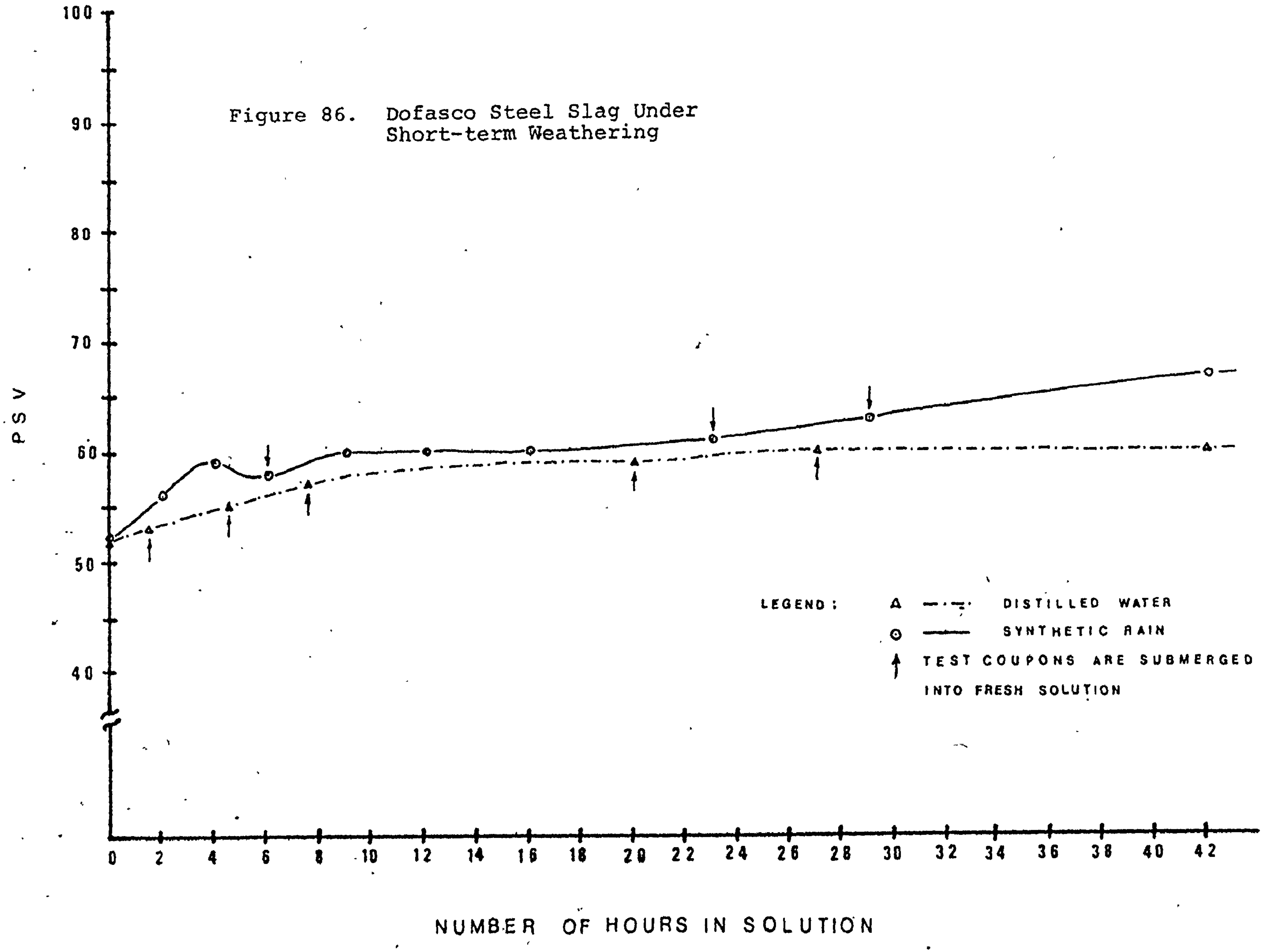


Figure 86. Dofasco Steel Slag Under Short-term Weathering



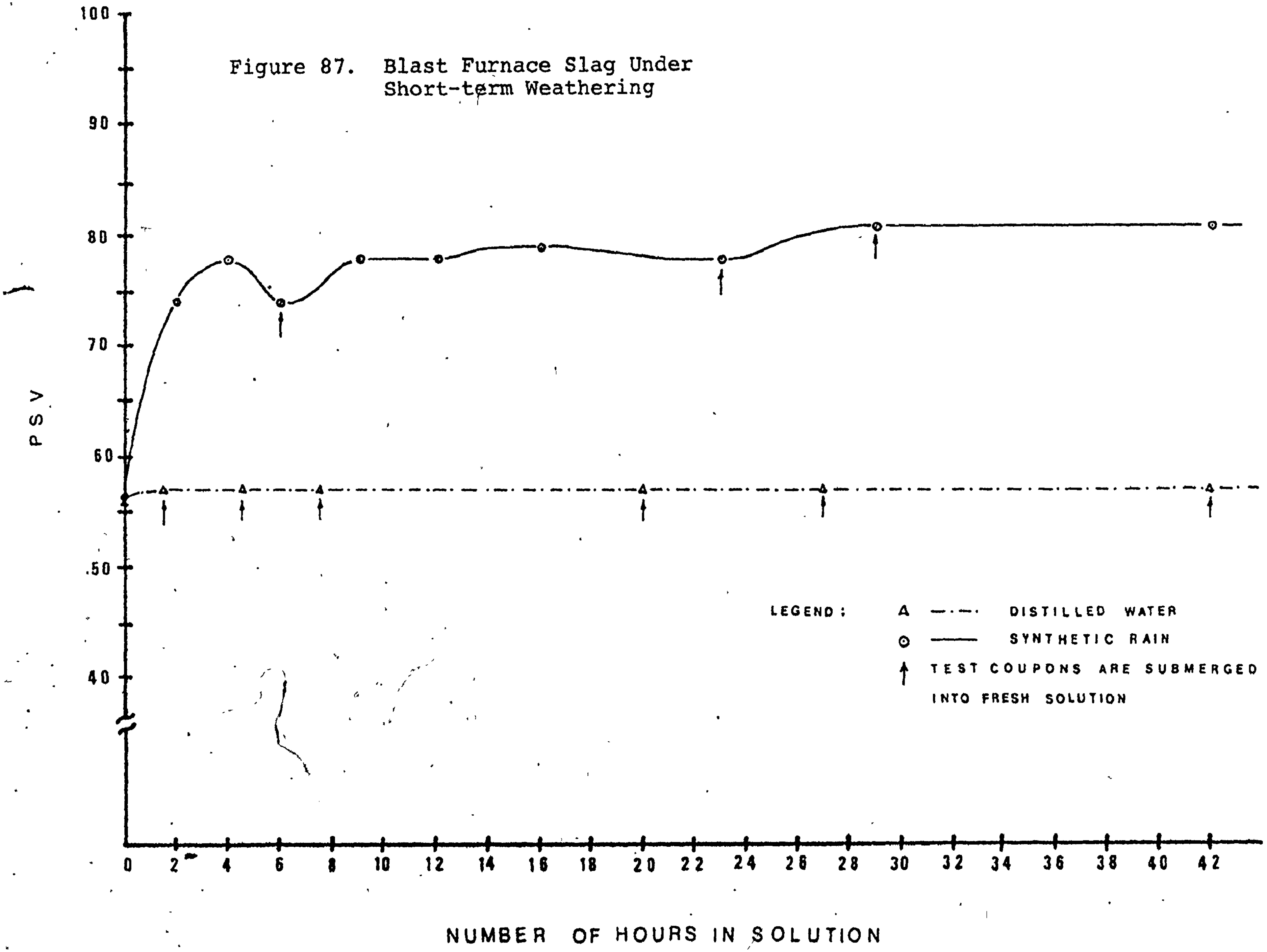


Figure 87. Blast Furnace Slag Under Short-term Weathering

6.6.2 LONG TERM WEATHERING IN 1% BY WEIGHT NaCl SOLUTION

The results of these tests shown in Figure 84 indicate that the NaCl solution did not affect skid resistance very much. However, comparing this study with the long-term weathering in $CaCl_2$ solution, the data in Table 20 show that test coupons in NaCl solution had greater increase in PSV than in $CaCl_2$ solution. Therefore, the use of NaCl on the road during the winter season will be slightly more advantageous to weathering skid resistance rejuvenation than the use of chemical ice-melt, which contains mainly $CaCl_2$. This is particularly the case for steel slag (i.e., 20% increase compared to 7% increase).

Table 20. Comparison of Long-term Weathering on NaCl Solution and $CaCl_2$ Solution

TYPE OF AGGREGATE	$CaCl_2$ solution			NaCl solution		
	INITIAL PSV	FINAL PSV	% INCREASE	INITIAL PSV*	FINAL PSV	% INCREASE
Traprock	45	48	7	46	52	13
Limestone	43	48	12	49	58	18
Steel slag	45	48	7	46	55	20
Blast furnace slag	55	58	5	53	59	11

* after re-polishing

The PSV of traprock increased to 52, which was the highest value recorded in the overall study. Therefore, this was used to establish the PRV of 52 for traprock in Table 18.

6.6.3 SHORT-TERM WEATHERING

In this testing program, only two types of solution were used: distilled water and synthetic rainwater. These two solutions were selected as they gave a good performance in previous studies. Because of the small influence of weathering, traprock was not included in the study.

The results of the short-term weathering study are shown in Figures 85 to 87. Observations from the test results can be summarized as follows:

1. Limestone

   The results of the short-term weathering study for limestone are given in Figure 85. As shown in this figure, there is a contrast in the performance of limestone in distilled water and synthetic rain. The maximum PSV obtained at the end of the test was 90 in synthetic rain and only 54 in distilled water. In some locations along the graph, the use of a fresh solution created a sudden increase in the PSV, expecially for test coupons submerged in synthetic rain.

2. Dofasco Steel Slag

As shown in Figure 86, Dofasco steel slag performed differently from limestone in the short-term weathering study. The performance of steel slag did not differ significantly in distilled water and in synthetic rain. The PSV of steel slag in synthetic rain starts to rise rather rapidly after 16 hours in the solution. The final PSV reading at the end of the test was 67 for the synthetic rain and 60 for the distilled water.

3. Blast Furnace Slag

The performance of blast furnace slag for the short-term weathering study was rather similar to limestone. As shown in Figure 87, the PSV of blast furnace slag increased rapidly in synthetic rain, but there was very little change of PSV in distilled water. The highest PSV obtained after 42 hours was 81, which is the PRV of blast furnace slag. The use of fresh solutions accelerated the PSV increase in synthetic rain; however, it did not affect the PSV readings in distilled water.

6.6.4 SUMMARY

The Special Studies can be summarized as follows:

1. The four aggregates, especially steel slag, had higher PSV increase in NaCl solution compared to $CaCl_2$ solution.
2. The final PSV readings for short-term weathering, together with the results from long-term weathering are summarized in Table 21. As shown in that table, the final PSV readings of the short-term weathering study were less than, or equal to, the PRV values which support the validity of the PRV concept.
3. In the cases where the PSV of the aggregate in any solution was far less than its PRV, the use of fresh solutions significantly accelerated the increase in PSV. On the other hand, once its PSV was close to the PRV, fresh solutions had little influence.
4. The data summarized in Table 21 support the argument that weathering can be accelerated into a short-term process. Within 42 hours, the PSV readings of the aggregates were already close to, or equal to their values after 42 days of weathering. A difference in procedure between long-term and short-term weathering was the use of fresh solutions. The fresh solution for long-term or cyclic weathering was introduced after

Table 21. PSV Results on Long-term and Short-term Weathering

TYPE OF AGGREGATE	TYPE OF SOLUTION	LONG-TERM : PSV after 42 Days	SHORT-TERM : PSV after 42 Hours
Limestone	Distilled water	60	54
	Synthetic rainwater	90	90
Dofasco steel slag	Distilled water	65	60
	Synthetic rainwater	72	67
Blast furnace slag	Distilled water	62	57
	Synthetic rainwater	81	81

each reading. Therefore, during long-term weathering this fresh solution was introduced over a much longer period of time. On the other hand, during short-term weathering, the fresh solution was available every few hours.

The frequency of the use of fresh solution affects the interaction between solution and aggregate. The tests showed that the chemical equilibrium occurred rather quickly. Once this equilibrium had been achieved, there was no further reaction. The time in which the equilibrium can be achieved depends on the concentrations of the chemicals within the system. However, short-term weathering tests showed that it occurs in relatively short time. Therefore, by increasing the frequency at which fresh solution is available to the aggregate surface (for instance, field precipitation during rainy season), the chemical reactions occur continuously. Finally, once the aggregate's PSV reaches its PRV, there is no more exposed surface to interact with the solution and the weathering reactions stop.

5. The concept of accelerated weathering has an important role in the overall study. This proves that a high aggregate PSV can be obtained within short time, such as during the duration of a rainfall. Further, since

fresh rain is involved continuously, the process of weathering can occur very quickly. Of course, the resistance of this new micro-texture to polishing will determine the final benefit to improved skid resistance.

6.7 RESULTS OF CHEMICAL ANALYSES ON WEATHERING PROCESS

6.7.1 RESULTS OF ANALYSES

Most of the processes of aggregate surface rejuvenation by rain and snow are chemical. As shown in Chapter 3, crystallization and/or formation of microcracks was observed for aggregates subjected to simulated weathering. The severity of the chemical reaction depends on the type of solution in which the aggregate was subjected to weathering and the chemical constituents of the aggregates. In previous sections of this chapter, it was also shown how changes in the PSV of the aggregate are caused by simulated weathering.

In this section, the results of chemical analyses of the weathering process are examined. Four types of aggregate - traprock, limestone (Canada Crush), blast furnace slag and Dofasco steel slag - were subjected to simulated weathering in five different solutions : distilled water; synthetic rainwater; rainfall water collected in Hamilton, Ontario on May 24th, 1979; 1% by weight $CaCl_2$ solution and 1% by weight NaCl solution. Chemical reactions which occurred due to the interactions of the aggregate and solution were then monitored for the solutions using a Hach Direct Reading kit and pH meter. The complete chemical analyses are provided in Appendix I.

The results of chemical analyses can be summarized as:

1. pH Reading

   The pH of all solutions increased after submersion of aggregates.

2. Dissolved CO_2

   The initial readings of the solutions showed that all of them contained the weak acid, H_2CO_3, even distilled water. H_2CO_3 exists from the presence of dissolved CO_2 in the solutions:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

3. Chloride $[Cl^-]$ in the solutions

   The concentration of chloride $[Cl^-]$ in the solutions:

   a. No change or little change occurred from initial readings for all aggregates in NaCl and $CaCl_2$ solutions; and traprock and limestone in distilled water and synthetic rain.

   b. Increases occurred for all aggregate in rainfall water; blast furnace slag and steel slag in distilled water; blast furnace slag in synthetic rain.

c. A decrease occurred for steel slag in synthetic rain.

4. Hardness (magnesium and total) in the solutions

The solution hardness, except for traprock in distilled water, increased after simulated weathering.

5. Total iron (not conducted for traprock and limestone) in the solutions

The concentration of total iron $[Fe^{2+,3+}]$ in all of the solutions increased after simulated weathering. Furthermore, the increase of $[Fe^{2+,3+}]$ in all of the solutions was much higher from steel slag than blast furnace slag.

6. Nitrates $[NO_3^-]$ in the solutions

The concentration of nitrates $[NO_3^-]$ in the solutions:

a. Decreased : limestone and blast furnace slag subjected in all solutions, traprock in distilled water and $CaCl_2$ solution; and steel slag in synthetic rain.

b. Increased : steel slag in distilled water, rainfall water, NaCl and $CaCl_2$ solutions.

c. No change : traprock in rainfall and NaCl solutions.

7. Sulphate $[SO_4^=]$ in the solutions

The concentration of sulphate $[SO_4^=]$ in the solutions increases for all tests, except for steel slag in rainfall water.

6.7.2 THEORETICAL BACKGROUND

Chemical reactions occur when two or more chemically active substances are mixed together. The degree to which the process occurs depends on the activity of each substance and the potential to form more stable substances. Rainfall contains mainly H_2O, sometimes with the presence of salts such as NH_4Cl, $Ca(NO_3)_2$, acids such as H_2SO_4, and dissolved $CO_2(H_2CO_3)$. During the winter, rock salt (NaCl) or ice-melt chemicals (mainly $CaCl_2$) is also present with the snow/water. Aggregates contain chemical constituents which depend on the specific aggregate type and source. For limestone, there are lots of carbonates (such as $CaCO_3$), $Ca(OH)_2$ and CaO present. For traprock, more stable chemical constituents exist such as Al_2SiO_3, MnO_2, MgO, etc. These minerals are common for basaltic type rocks. For steel slag, FeO/CaO combinations occur, whereas for blast furnace slag, there is much less steel present with mostly CaO and/or MgO.

With the presence of these chemical constituents, when rainfall water meets the aggregate, three types of chemical reaction may occur depending on how active the constituents are:

1. The formation of crystals

Crystals can be formed as a result of chemical reactions, such as:

Acid solution + basic solution → salt (crystals)↓ + H_2O

Acid solution + basic oxide → salt (crystals)↓ + H_2O

Acidic oxide + base → salt (crystals)↓ + H_2O

Crystals can also be formed as a result of one way equilibrium reaction . In most cases, the chemical constituents in either aggregates or rainwater independently are in a state of equilibrium. However, the contact of solutions and aggregate disturbs the equilibrium condition and results in one way reactions, for example:

$$A + B \rightleftharpoons 2C\downarrow + D$$

$$k = \frac{[C]^2\,[D]}{[A] \times [B]}$$ equilibrium constant

If the concentration of A increases due to the availability of this chemical constituent (either from the aggregate or solution), the equilibrium equation will be disturbed; and since K is a constant, the concentration of either C or D must increase or B decreases.

If C or D increases, a one-way reaction may occur by increasing concentration of A as follows.

$$\underset{\underset{[A]\ \text{increases}}{\uparrow}}{A} + B \longrightarrow \underset{\text{crystals}}{2C\downarrow} + D$$

2. The formation of microcracks (leaching)

As shown in Chapter 3, Section 6, microcracks formed on the surface of the steel slag that can be seen in the SEM. These cracks are basically caused by leaching of Fe and/or Ca from the FeO/CaO constituents on the slag surface.

3. Combination of crystallization and leaching

Chemical constituents which are leached into the solution can disturb the original equilibrium of the solution, resulting in crystallization and deposition on top of the aggregate surfaces.

6.7.3 INTERPRETATION OF THE TEST ANALYSES

The interpretation of the chemical analyses is summarized as follows:

1. Traprock

The test results show that the chemical reactions which occur between the traprock and all four types of solution, especially with distilled water are very limited. This is in accord with the small changes in

PSV observed due to weathering.

2. Limestone

The natural environment of limestone is alkaline due to the abundance of CaO and/or $Ca(OH)_2$ with the presence of water. The pH readings which showed an increase of pH of the solution, indicate that the more acidic solutions of distilled water, rainfall water and synthetic rain have been neutralized and become alkaline through chemical reaction with limestone. Chemical tests on the solutions show significant increases in total hardness and decreases in $[NO_3^-]$. The small changes of $[Cl^-]$ in the NaCl and $CaCl_2$ solutions might be attributed to test readings since the solutions had to be diluted 50X prior to testing. It is anticipated that $[Cl^-]$ in the solution is being depleted through chemical reactions with limestone. As a result, many crystals of both $MgCl_2/Mg(NO_3)_2$ and $CaCl_2/Ca(NO_3)_2$ are formed on the surface of the limestone, which significantly change its PSV. These crystals are soft and easily broken during abrasion and polishing. Other crystals which may form during the chemical process are Ca SO_4 and Mg SO_4. These crystals may only form for limestone submerged in distilled water, synthetic rain and rainfall water. For limestone in NaCl and Ca Cl_2, the increase of $[SO_4^=]$ is limited due to the presence of [Cl^-] in the solution. An abundance [Cl^-] inhibits the formation of either dissolved Ca SO_4/Mg SO_4 and/or crystals of Ca SO_4/Mg SO_4.

As shown in previous sections of this chapter, the PSV increase of limestone in NaCl and $CaCl_2$ is less significant in comparison to limestone in synthetic rain and rainfall water. This can be attributed to the presence of abundant [Cl^-] as mentioned above. The PSV increase for limestone in distilled water is small due to smaller change of concentrations of total hardness and Nitrate [NO_3^-] in the solution.

3. Blast furnace slag

The chemical analysis of blast furnace slag showed an abundance of SiO_2, Al_2O_3, CaO, MgO, some Fe, FeO, Mn O, and S (in SO_3 or S) (14). Basically, slag contains more basic oxides which have the potential to form crystals during reactions with acid solutions. Therefore, as shown in previous sections, PSV changes occur most drastically for blast furnace slag submerged in synthetic rain, which had an initial pH of 2.4.

Concentration of total iron and total hardness in the solutions increased, which indicate that basic oxides as well as Fe were depleted from the aggregate into the solutions. The large increase of [$SO_4^=$] signifies that S or SO_3 is being depleted into the solution, which can be identified by their strong odours.

4. Steel slag

The chemical process for steel slag under simulated weathering showed almost the same pattern to the blast furnace slag, except that the $[NO_3^-]$ in solutions increased. Chemical analyses also indicate that blast furnace slag is more active under the weathering process in terms of formation of crystals. This also indicates that the temporary change of PSV showed that blast furnace slag performed slightly better under weathering than steel slag. However, having a higher concentration of Fe and the potential of forming microcracks, in the long-term steel slag has proven to be somewhat superior than blast furnace slag. As shown in Chapter 3, negative rejuvenation plays an important role in long-term PSV performance.

7 SUMMARY OF THE STUDY

7.1 SURFACE TEXTURE

For asphaltic concrete surface courses, the surface texture of the exposed coarse aggregate is the key factor influencing the skid resistance performance of the pavement. This texture provides friction between tires and the road for all weather conditions, and it also provides drainage paths for the water film during the interaction between tires and pavement in wet conditions. Surface texture can be divided into two parts : micro texture, which provides most of the skid resistance at lower speeds (up to about 60 km/h) and macro texture which is more important at higher speeds during wet conditions.

Dynamic processes, such as polishing, wear on abrasion, and weathering occur at the aggregate surface. These interactive processes tend to reduce or increase the quality of the surface texture. Therefore, at any given time, the surface texture depends on the traffic and environmental conditions, and the physical and chemical characteristics of the aggregates involved.

While past laboratory and field studies have yielded much information on polishing and abrasion, the main purpose of this study was to develop both qualitative and quantitative analyses and data for the dynamic processes which occur on the aggregate surface. Scanning electron microscope observations were completed on both field and laboratory samples to evaluate the polishing, abrasion and weathering processes. Chemical and x-ray diffraction analyses were also completed in order to explain the mechanisms and chemistry involved during the weathering process. Laboratory tests were completed to obtain quantitative information on the weathering effects on skid resistance performance (i.e., PSV).

A summary of the study is given in the following sections with an indication of the main findings and further research needs.

7.2 NEW CONCEPT DEVELOPED FROM THE STUDY

7.2.1 POSITIVE AND NEGATIVE REJUVENATING PROCESSES

The positive and negative rejuvenating processes are weathering processes on the aggregate surface caused by precipitation, and in some cases by the use of chemicals during winter periods (i.e., ice melters, salt, etc.).

Positive rejuvenation occurs as a result of chemical reaction between the aggregate surface and the solution (precipitation), in which crystals form on the surface and grow with time. The crystals formed depend on the type of aggregate and solution, and in some cases, the crystal growth can be very extensive (limestone, for instance).

In contrast, negative rejuvenation is caused by the leaching of aggregate components into the solution, creating microcracks on the surface of the aggregate. For steel slag, the unique CaO/FeO composition and calcium aluminoferrite results in the development of deep microcracks which enhance the skid resistance performance. In general, both of these processes occur during weathering; however, their effectiveness in enhancing long-term skid resistance depends on the hardness of the surface texture (resistance to polishing and abrasion), chemical composition of both the aggregate and the solution, rate of the process, and chemical reactions between the components.

7.2.2 POTENTIAL REJUVENATING VALUE (PRV)

The Potential Rejuvenating Value (PRV) is a potential value to which the polished or repolished surface of the aggregate can rejuvenate during any weathering process. The PRV is an upper bound PSV, and it only develops under conditions in which no polishing or abrasion interacts with the weathering process. The PRV for aggregates, as qualitatively measured in the study were : 52 for traprock; 90 for limestone; 72 for Dofasco steel slag; and 81 for blast furnace slag.

The PRV is only a potential value, which explains how much rejuvenation can occur on polished aggregate surfaces. Its value does not represent the "quality" of skid resistance performance for an aggregate, since other factors such as PSV and AAV govern skid resistance performance. However, its value can provide information on the behaviour of aggregates under weathering conditions, such as chemical activity, stability of aggregate components, etc.

7.3 LABORATORY STUDY OF WEATHERING (QUANTITATIVE ANALYSES)

Basically, the laboratory study was divided into three parts : long-term weathering; short-term weathering; and cyclic weathering. From both the long-term and short-term weathering studies, the Potential Rejuvenating Value concept was developed. The cyclic weathering study indicated that weathering only occurs during the contact of the aggregate surface and the solution (precipitation).

Dry cycles resulted in no PSV changes, while rejuvenation occurred and continued during wet cycles.

The short-term weathering study indicated that the process occurring on the road during precipitation is accelerated weathering, since during precipitation new, fresh water is always introduced to the surface of the aggregates. Therefore, the findings from the long-term weathering study can be applied to both short-term weathering and the actual weathering at the road.

In general, the simulated weathering due to synthetic rain provided the highest PSV increase, while the simulated weathering due to $CaCl_2$ or NaCl solution was found to inhibit the rejuvenating process. Limestone was found to be the most active aggregate during the weathering process, while there was little weathering of the traprock.

7.4 CHEMICAL AND X-RAY DIFFRACTION ANALYSES

Both the chemical and x-ray diffraction analyses were found to be useful in supporting the findings from the other parts of the study. The chemical analyses, which provided information on the chemical process of weathering, and the x-ray diffraction analyses, which provide information on both the surface characteristics and the crystals formed, indicated that the weathering process during precipitation is a purely chemical process. Chemical analyses revealed that since aggregates consist of many oxides and/or hydroxides, the solutions (precipitation) which are acidic (such as urban and industrial rains) greatly effect the weathering process. On the other hand, the presence of salts generally inhibit the chemical weathering process.

The x-ray diffraction analyses indicated that, in general, the crystals formed on the surface of the aggregate have the same composition as the composition of the aggregate surface. This confirmed that these crystals were formed as the result of chemical reactions between the aggregate surface and the solution.

7.5 SCANNING ELECTRON MICROSCOPE (SEM) OBSERVATIONS

The SEM was used to observe the effect of polishing, abrasion and weathering on the aggregate surface texture. Aggregate samples which were subjected to polishing, abrasion and weathering in highway test sections, as well as sample subjected to the same processes in the laboratory were examined in the SEM. These observations revealed that the polishing process tends to effect the micro-texture of the aggregate, while wear or abrasion effects both the macro texture and the micro-texture. The micro-texture quality after abrasion depends on the initial micro-texture and the physical and chemical characteristics of the aggregates.

Further observations on both laboratory and field samples revealed that micro-texture is an important factor which establishes the PSV of an aggregate. Furthermore, secondary micro-texture is the key to high, long-term skid resistance performance of aggregates. Core samples taken from the Highway 401 Test Sections showed that steel slag, which has a medium secondary micro-texture, and medium to high primary micro-texture, has a good PSV.

Finally, the concept of positive and negative rejuvenating processes was introduced as a major contribution of the SEM study.

7.6 RECOMMENDATIONS AND FUTURE WORK

The primary goal of the study was to evaluate four types of aggregate that are readily available in Ontario for use in skid resistant asphaltic concrete surface courses. The study revealed that an "ideal" aggregate should have a good resistance to both polishing and abrasion, as well as the potential for rejuvenation during weathering.

Steel slag, with its good natural primary micro-texture and secondary micro-texture, its resistance to abrasion and polishing, and its unique CaO/FeO composition was found to be the most desirable aggregate evaluated in terms of potential skid resistance. This is generally in accord with field observation. Therefore, the continuing use of steel slag in asphaltic concrete mixes is one way to reduce skidding accidents during the provision of high quality pavements.

In summary, the study yielded a lot of information about the surface texture of aggregates used in Ontario's asphaltic concrete surface courses, its influence on skid resistance and effect of weathering. However, the study should be continued as there is much more scope for further work:

a. Influences of the combined action of polishing and weathering.

An introduction to this aspect of skid resistance was completed in the study, and showed some interesting findings such as the resistance to PSV lowering during re-polishing of steel slag, which may be due to the development of microcracks on its surface. However, further research is needed in this area.

b. Weathering influences on the skid resistance of field test sections.

In addition to the laboratory tests, highway test section observations should be made on a daily or weekly basis to provide information on seasonal and short-term weathering influences on skid resistance where traffic action is also involved.

c. Skid resistance study on mixed aggregates

Initial finding in this study revealed that the presence of small portion of high skid resistance aggregate might improve the aggregate mix as a whole. Therefore, further research is needed to develop the types and proportions of aggregate in the mixes, in order to yield the best skid resistance performance.

8. APPENDICES :

APPENDIX A :

X-RAY EMISSION ENERGIES FOR THE XRD ANALYSIS

Table A.1. X-ray Emission Energies in keV

Atomic Number	Element	$K_{\beta\ell}$	$K_{\alpha\ell}$	$L_{\beta\ell}$	$L_{\alpha\ell}$
1	Hydrogen				
2	Helium				
3	Lithium		0.052		
4	Beryllium		0.110		
5	Boron		0.185		
6	Carbon		0.282		
7	Nitrogen		0.392		
8	Oxygen		0.523		
9	Fluorine		0.677		
10	Neon		0.851		
11	Sodium	1.067	1.041		
12	Magnesium	1.297	1.254		
13	Aluminum	1.555	1.487		
14	Silicon	1.832	1.740		
15	Phosphorus	2.136	2.015		
16	Sulphur	2.464	2.308		
17	Chlorine	3.815	2.622		
18	Argon	3.192	2.957		
19	Potassium	3.589	3.313		
20	Calcium	4.012	3.691		
21	Scandium	4.460	4.090		
22	Titanium	4.931	4.510		
23	Vanadium	5.427	4.952		
24	Chromium	5.946	5.414		
25	Maganese	6.490	5.898		
26	Iron	7.057	6.403		
27	Cobalt	7.649	6.930		
28	Nickel	8.264	7.477		
29	Copper	8.904	8.047	0.948	0.928
30	Zinc	9.571	8.638	1.032	1.009
31	Gallium	10.263	9.251	1.122	1.096
32	Germanium	10.981	9.885	1.216	1.186
33	Arsenic	11.725	10.543	1.317	1.282
34	Selenium	12.495	11.221	1.419	1.379
35	Bromine	13.290	11.923	1.526	1.480
36	Krypton	14.112	12.648	1.638	1.587
37	Rubidium	14.960	13.394	1.752	1.694
38	Strontium			1.872	1.806
39	Yttrium			1.996	1.922
40	Zirconium			2.124	2.042

(continued)

Atomic Number	Element	$L_{\beta l}$	$L_{\alpha l}$	$M_{\alpha l}$
41	Niobium	2.257	2.166	
42	Molybdenum	2.395	2.293	
43	Technetium	2.538	2.424	
44	Ruthenium	2.683	2.558	
45	Rhodium	2.834	2.696	
46	Palladium	2.990	2.838	
47	Silver	3.151	2.984	
48	Cadmium	3.316	3.133	
49	Indium	3.487	3.287	
50	Tin	3.662	3.444	
51	Antimony	3.843	3.605	
52	Tellurium	4.029	3.769	
53	Iodine	4.220	3.937	
54	Xenon	4.422	4.111	
55	Cesium	4.620	4.286	
56	Barium	4.828	4.467	
57	Lanthanum	5.043	4.651	0.033
58	Cerium	5.262	4.840	0.883
59	Prasceodymium	5.489	5.034	0.929
60	Neodymium	5.722	5.230	0.978
61	Promethium	5.956	5.431	
62	Samarium	6.206	5.636	1.081
63	Europium	6.456	5.846	1.131
64	Gadolinium	6.714	6.059	1.185
65	Terbium	6.979	6.275	1.240
66	Dysprosium	7.249	6.495	1.293
67	Holmium	7.528	6.720	1.348
68	Erbium	7.810	6.948	1.406
69	Thulium	8.103	7.181	1.462
70	Ytterbium	8.401	7.414	1.521
71	Lutecium	8.708	7.654	1.581
72	Hafnium	9.021	7.898	1.645
73	Tantalum	9.341	8.145	1.710
74	Tungsten	9.670	8.396	1.775
75	Rhenium	10.008	8.651	1.843
76	Osmium	10.354	8.910	1.910
77	Iridium	10.706	9.173	1.980
78	Platium	11.069	9.441	2.051
79	Gold		9.711	2.123
80	Mercury		9.987	2.195
81	Thallium		10.266	2.271
82	Lead		10.549	2.346
83	Bismuth		10.836	2.423
84	Polonium		11.128	

APPENDIX B :

MTC ASPHALTIC CONCRETE PAVEMENT TEST SECTIONS : HIGHWAY 401, TORONTO BYPASS

B.1 LOCATION OF TEST SECTIONS

The MTC test sections are located on Highway 401 (Toronto Bypass). They were constructed on a 2.4 km section of the westbound express lanes immediately west of the Allen Expressway. The sections consist of 18 individual asphaltic concrete overlay sections, and each of them varies in its type of mix and/or aggregate content.

B.2 TRAFFIC DATA

The average daily traffic volumes for each of the three traffic lanes are shown in Table B.1 (16). The traffic data are based on recordings from 28, twenty-four hour periods in 1975.

Table B.1. Traffic Data on Highway 401

DESCRIPTION	DRIVING LANE	CENTRE LANE	PASSING LANE
Total vehicles per day	12900	17300	14600
Commercial vehicles per day	3740	1900	150

B.3 ASPHALTIC CONCRETE MIX DESIGN INFORMATION

Table B.2 shows all of the information about the test sections which is relevant to the study. Further information about the test sections is available in the report by Ryell, et al (16).

Table B.2. Asphaltic Concrete Mixes, Composition and Design Data of Highway 401 Test Sections

TEST SECTION	MIX TYPE	COARSE AGGREGATE + No. 4 *	FINE AGGREGATE - No. 4 *
1	HL 1	45TR	41NS 14LS
2	HL 1	45TR	41NS 14TRS
3	HL 1	45TR	55TRS
4	HL 1	55TR	34NS 11LS
5	HL 1	60TR	28NS 10LS
6	HL 1	60TR	38TRS
7	Modified HL 1	45SL	55SLS
8	Modified HL 1	50SL	38NS 12LS
9	Modified HL 1	45BF	55BFS
10	Modified HL 1	40BF	45NS 15LS
11	Sand Mix	14TR	84TRS
12	Sand Mix	9TR	89TRS
13	Open Graded	67TR	33TRS
14	Open Graded	67TR	31TRS
15	Open Graded	30TR	70TRS
16	Open Graded	30TR	68TRS
17	Mastic	70TR	19TRS
18	HL 1	45TR	41NS 14LS

<u>Notes</u>: * Number indicates percent weight of aggregate
NS : natural sand S : screenings

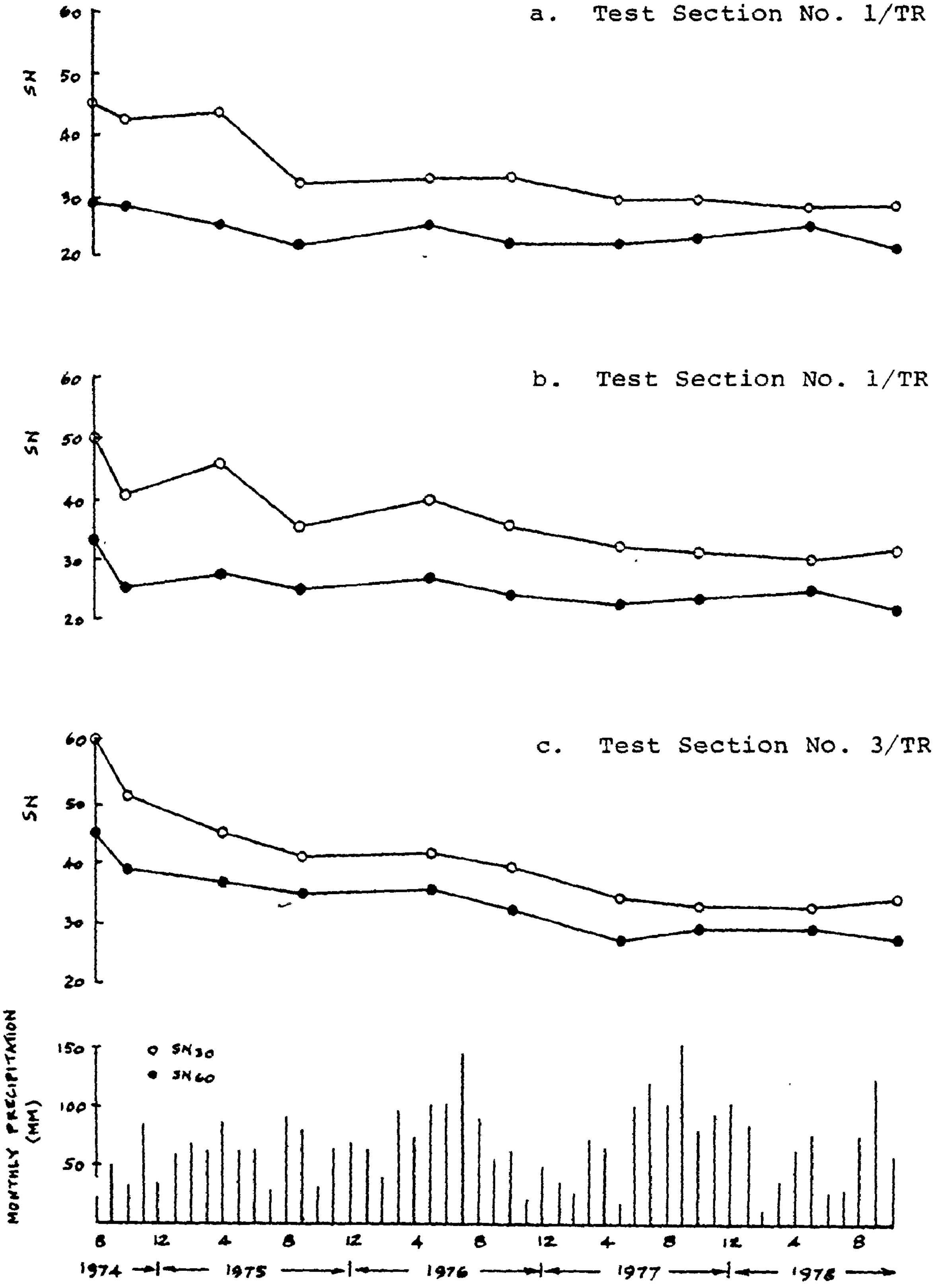
APPENDIX C :

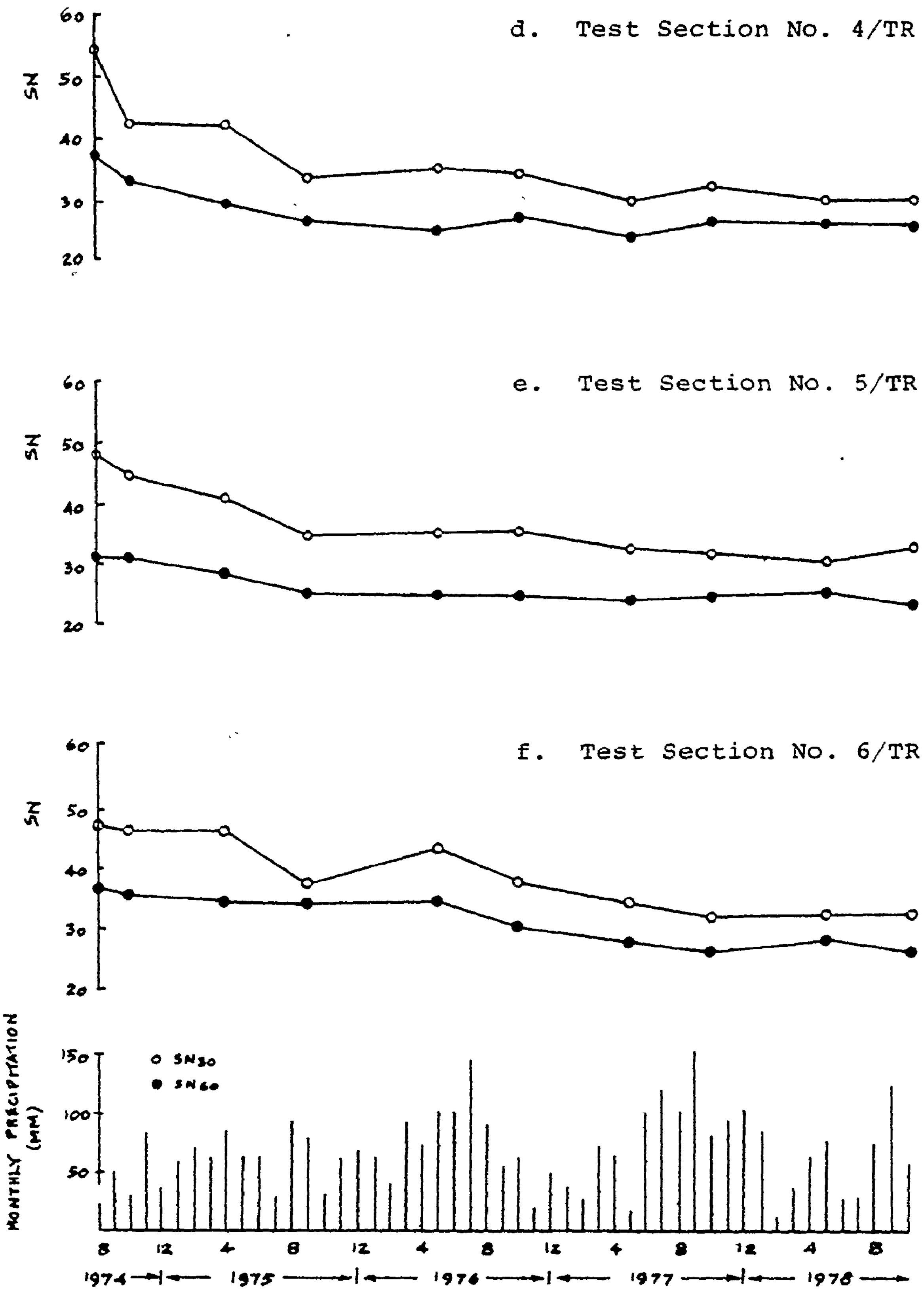
WEATHERING INFLUENCES ON HIGHWAY 401 TEST SECTIONS

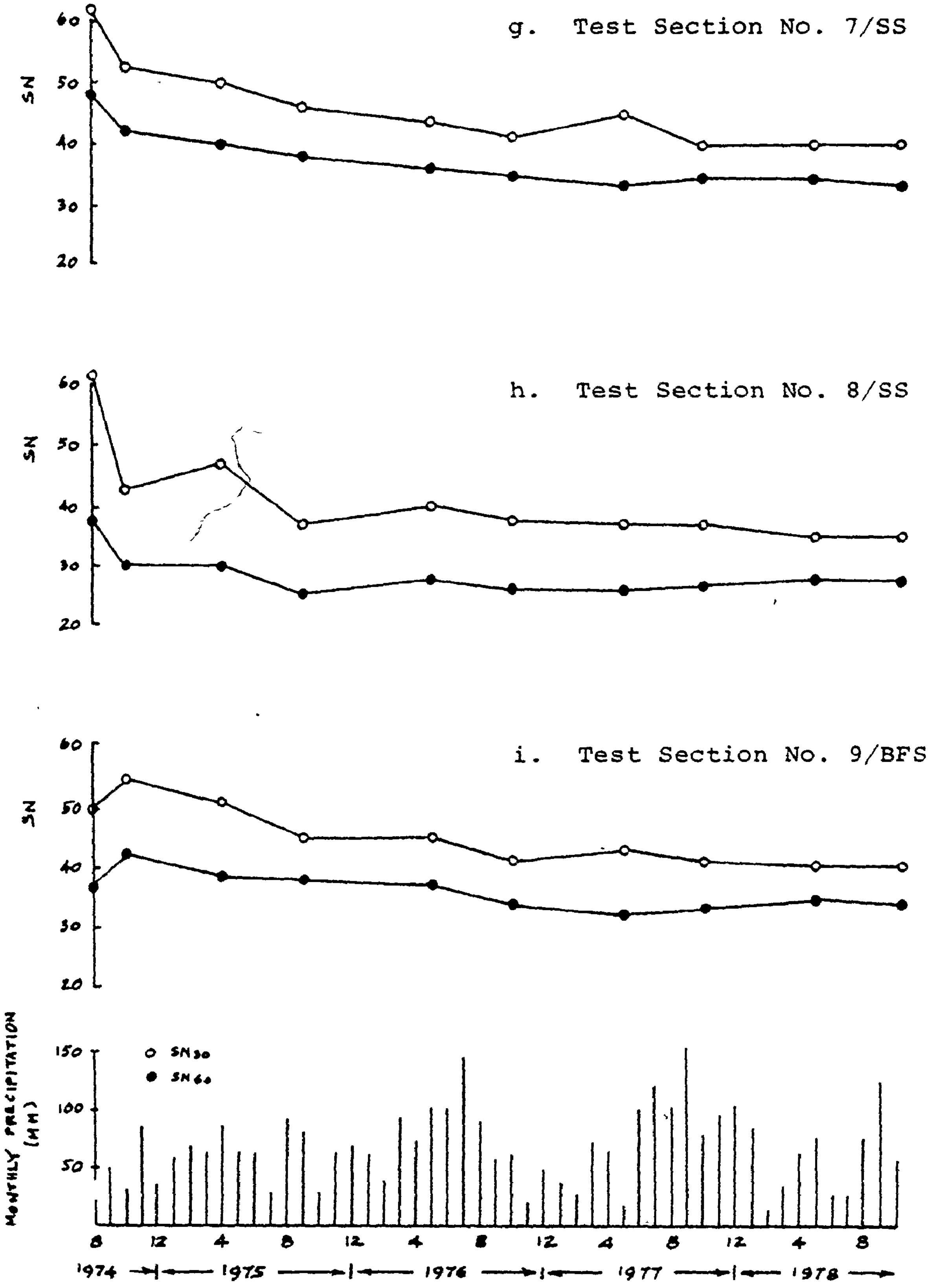
Figure C-1. Weathering Influences on Highway 401 Test Sections : Driving Lane

Note:

Precipitation readings were obtained from Downsview Airport, which is the closest Meteorological Station to the test sections (23).


a. Test Section No. 1/TR
b. Test Section No. 1/TR
c. Test Section No. 3/TR
SN
60
50
40
30
20
MONTHLY PRECIPITATION (MM)
150
100
50
○ SN30
● SN60
8
12
4
8
12
4
8
12
4
8
12
4
8
1974
1975
1976
1977
1978


d. Test Section No. 4/TR
SN
60
50
40
30
20
e. Test Section No. 5/TR
SN
60
50
40
30
20
f. Test Section No. 6/TR
SN
60
50
40
30
20
MONTHLY PRECIPITATION (MM)
150
100
50
○ SN30
● SN60
8
12
4
8
12
4
8
12
4
8
12
4
8
1974
1975
1976
1977
1978

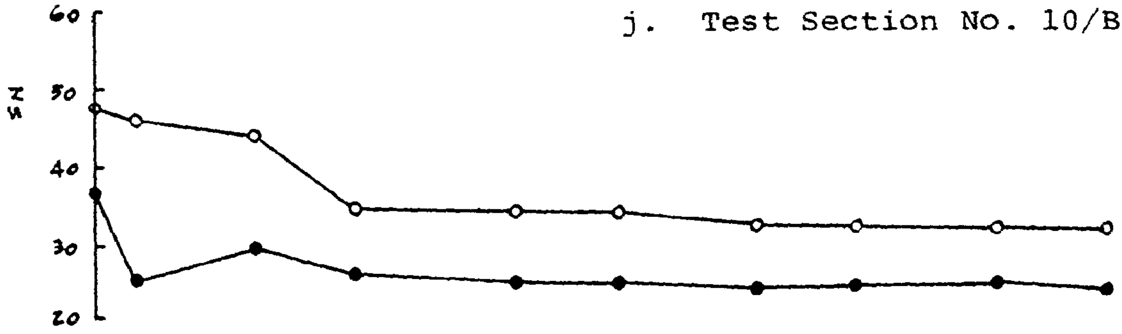


g. Test Section No. 7/SS

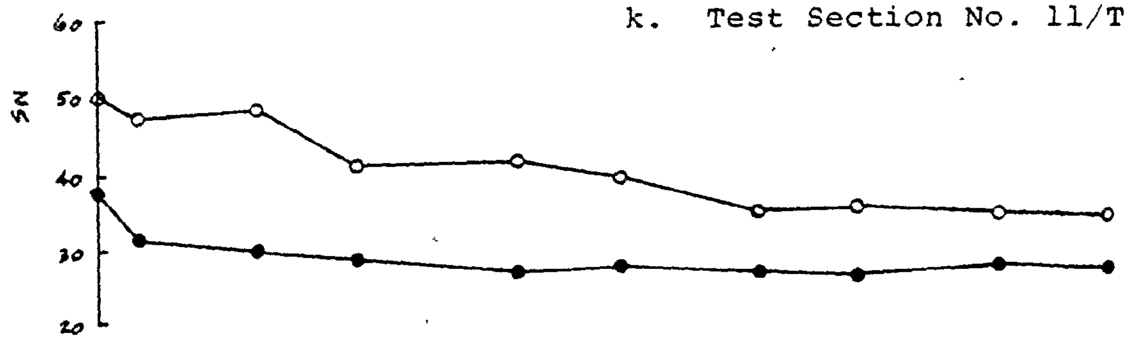
h. Test Section No. 8/SS

i. Test Section No. 9/BFS

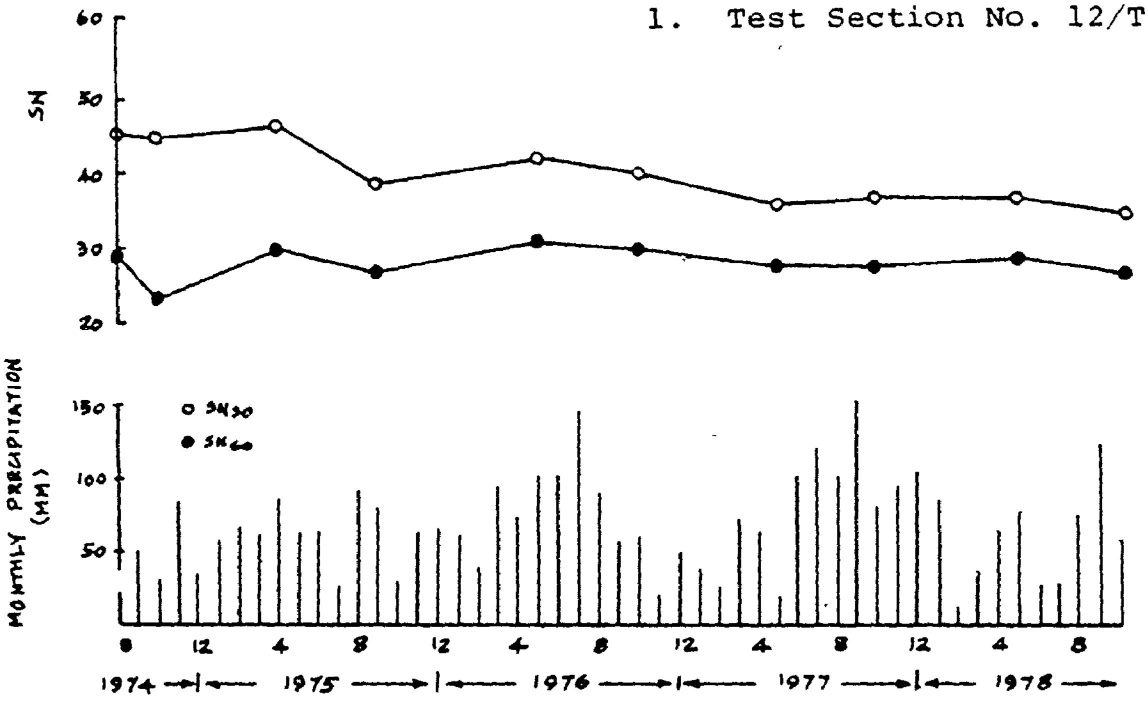
j. Test Section No. 10/BFS

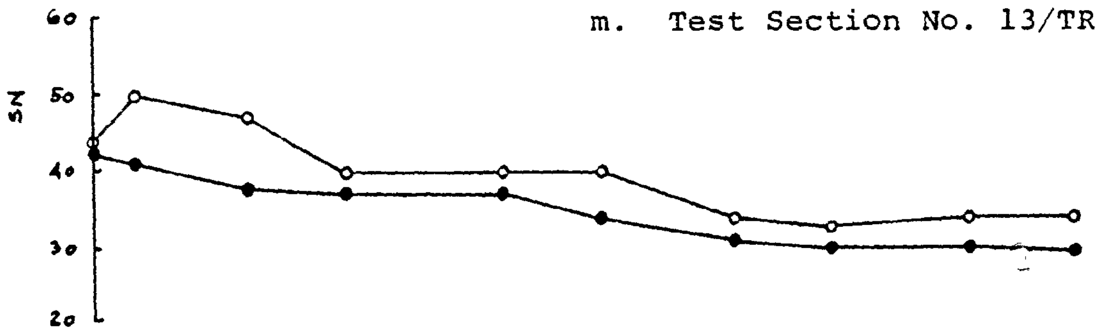


k. Test Section No. 11/TR

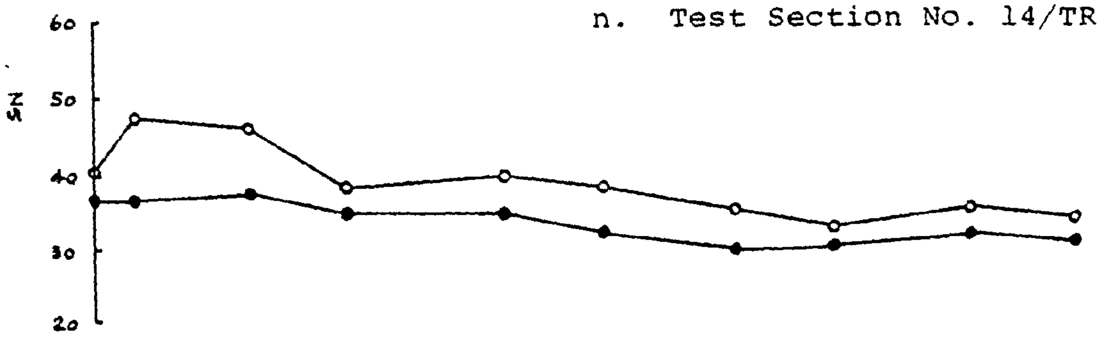


l. Test Section No. 12/TR

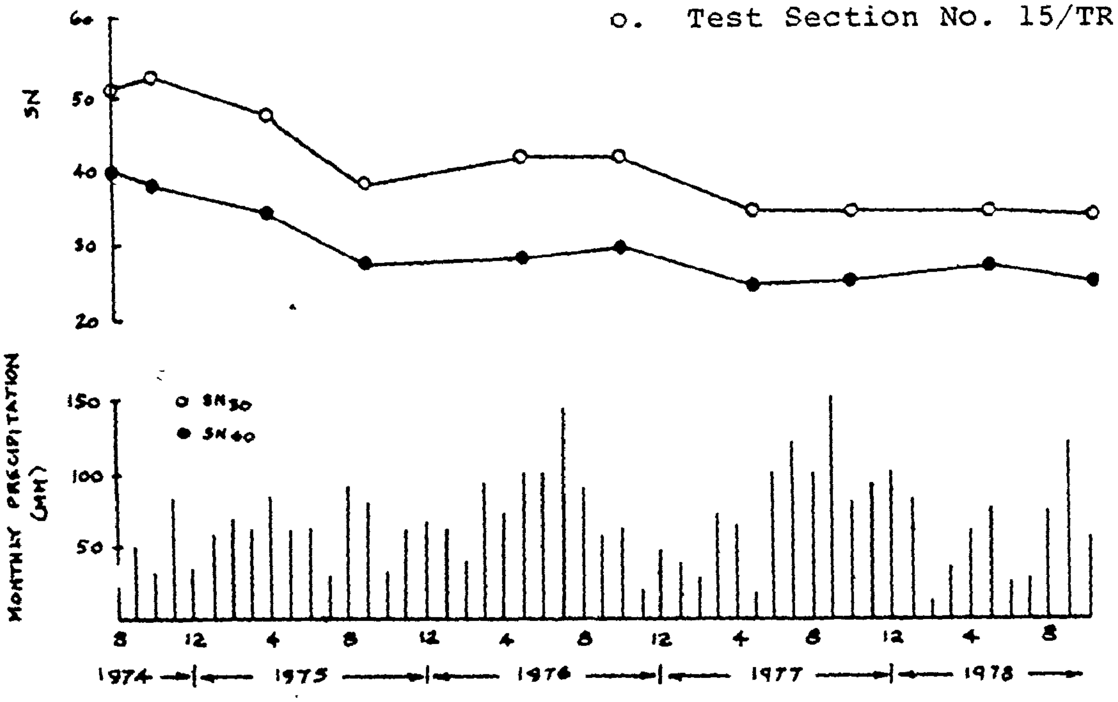




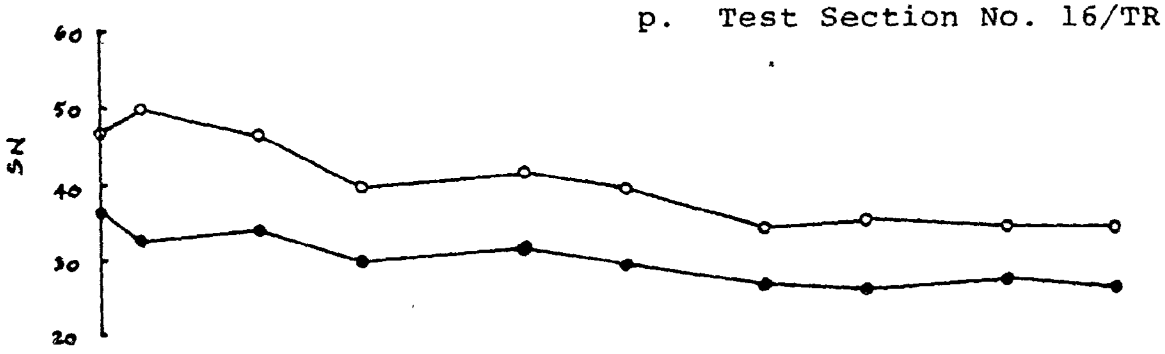
m. Test Section No. 13/TR



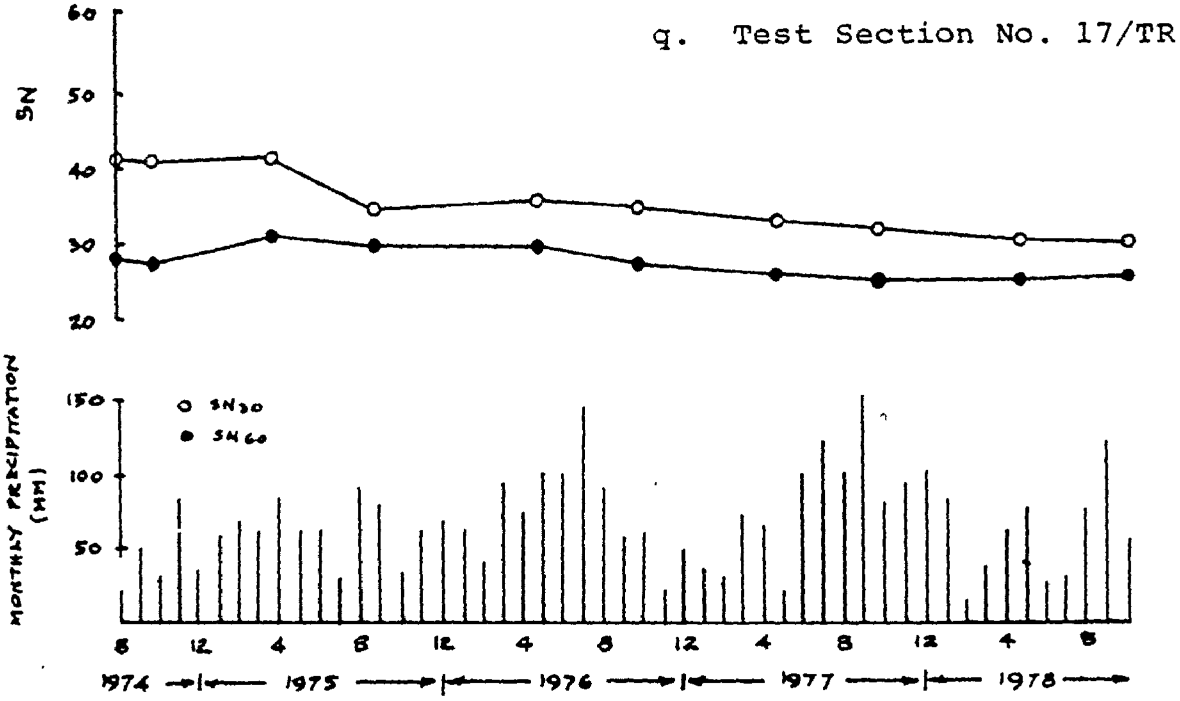
n. Test Section No. 14/TR



o. Test Section No. 15/TR



p. Test Section No. 16/TR

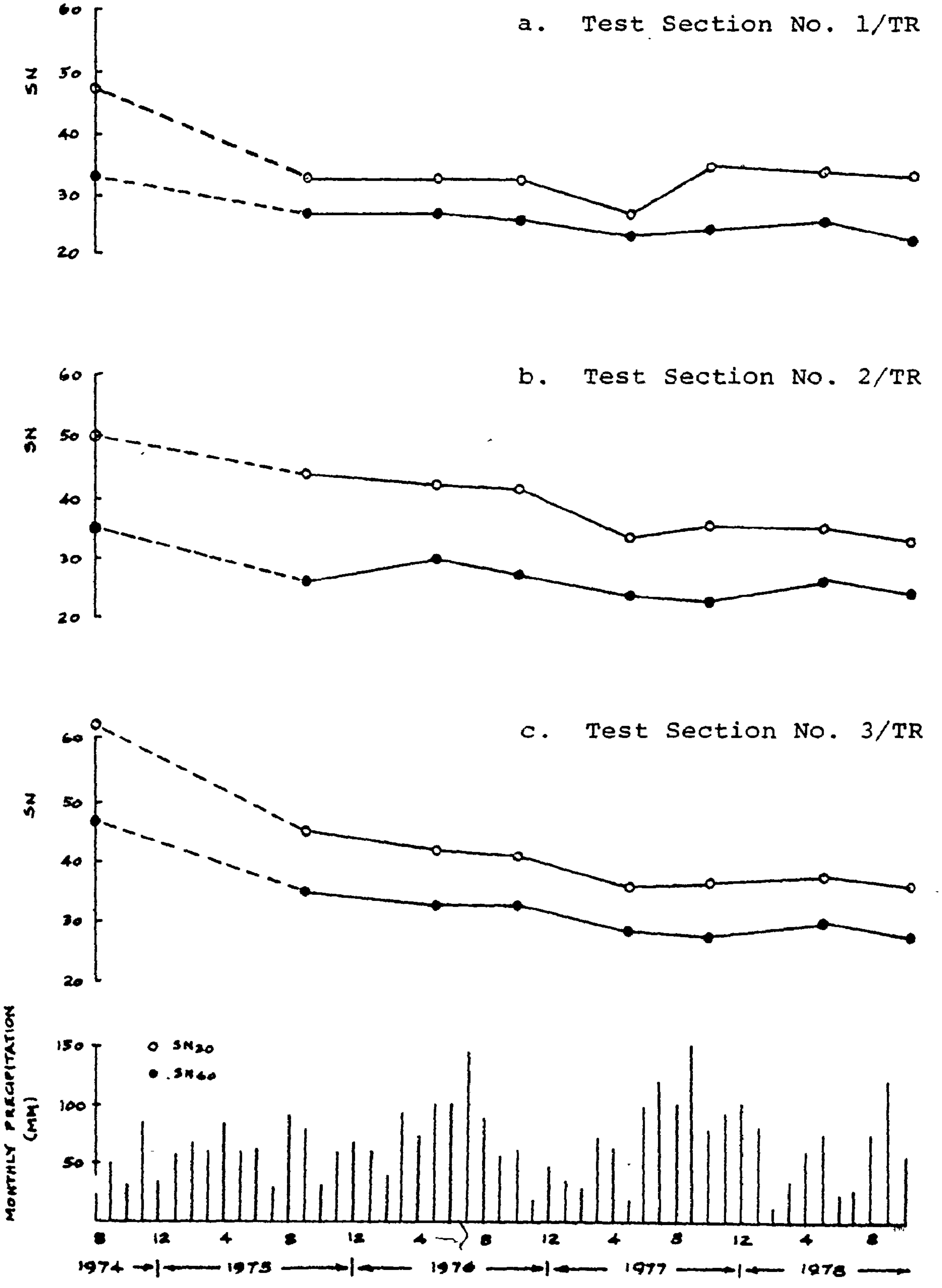


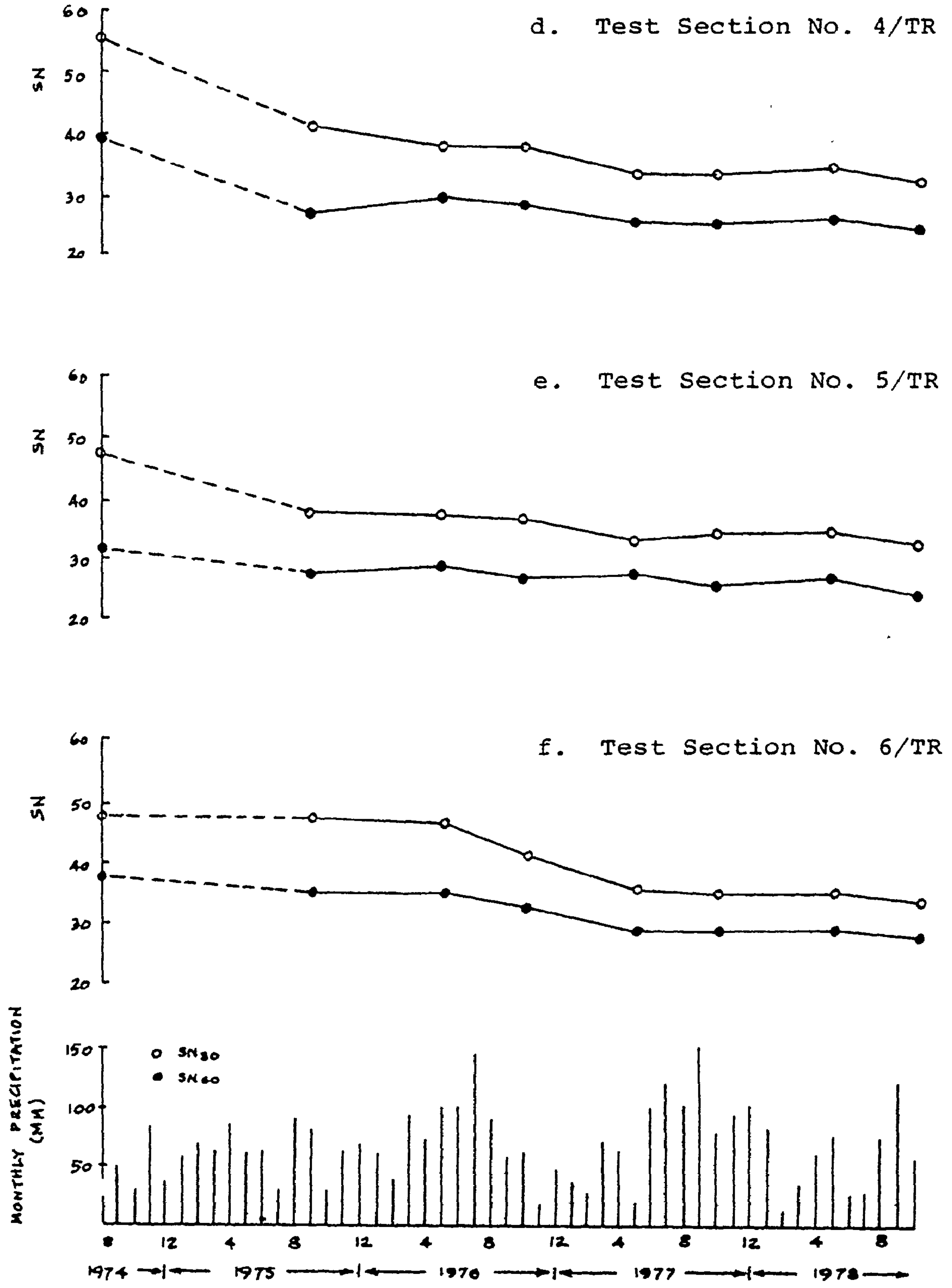
q. Test Section No. 17/TR

Figure C-2. Weathering Influences on Highway 401 Test Sections : Centre Lane

Note:

Precipitation readings were obtained from Downsview Airport, which is the closest Meteorological Station to the test sections (23).

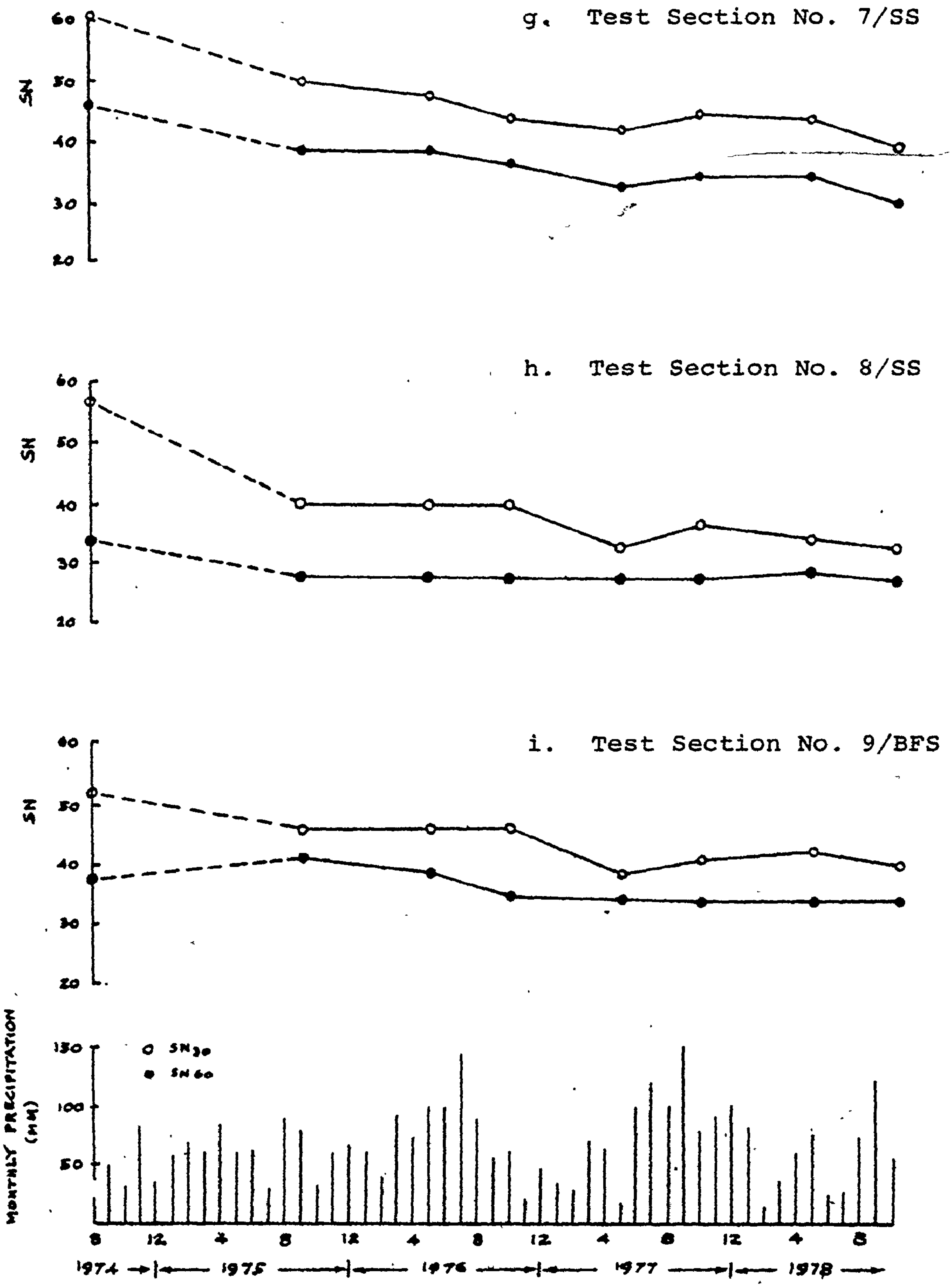

a. Test Section No. 1/TR
b. Test Section No. 2/TR
c. Test Section No. 3/TR
SN
60
50
40
30
20
MONTHLY PRECIPITATION (MM)
150
100
50
o SN20
• SN60
8
12
4
8
12
4
8
12
4
8
12
4
8
1974
1975
1976
1977
1978



d. Test Section No. 4/TR

e. Test Section No. 5/TR

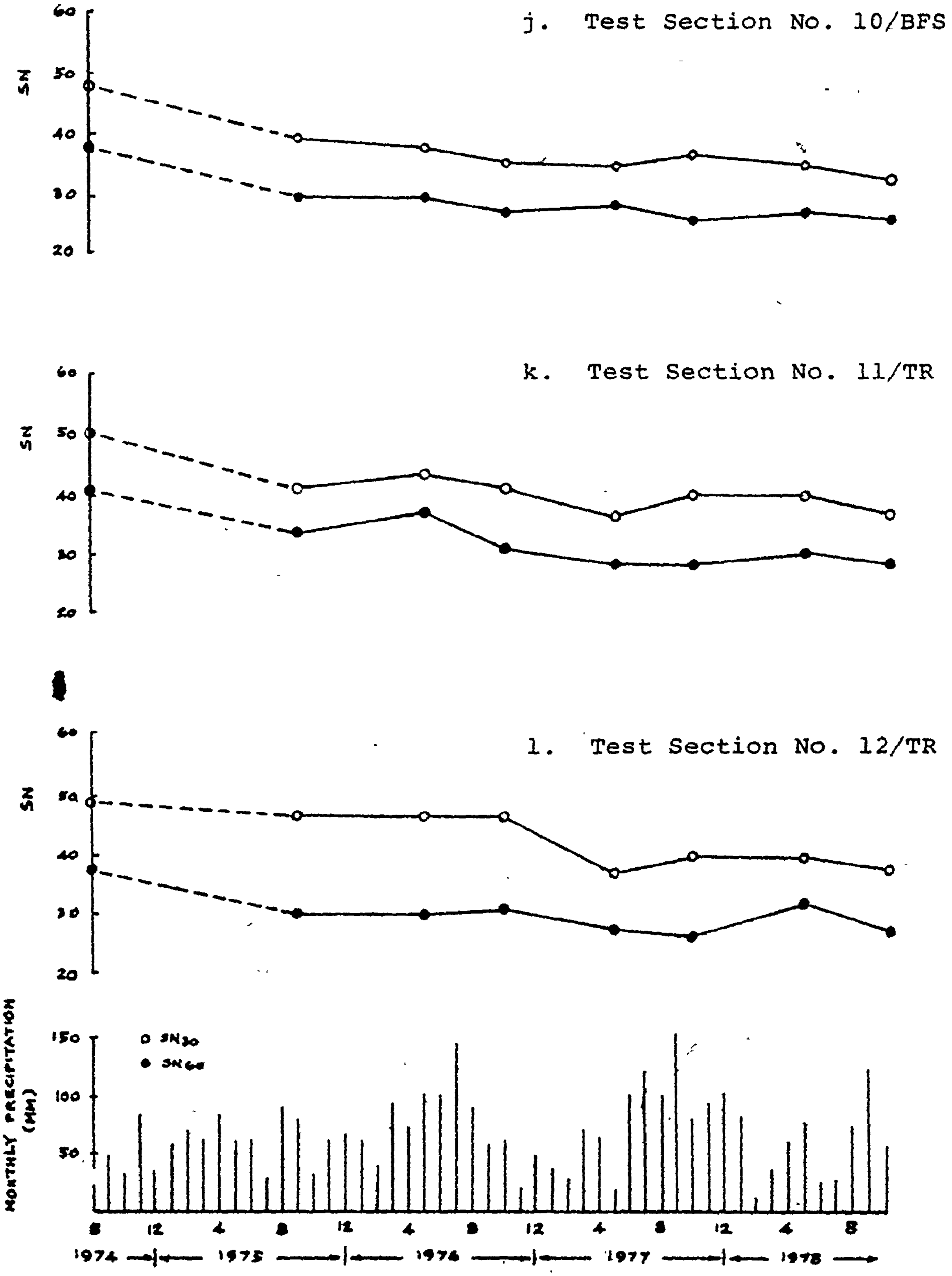
f. Test Section No. 6/TR



g. Test Section No. 7/SS

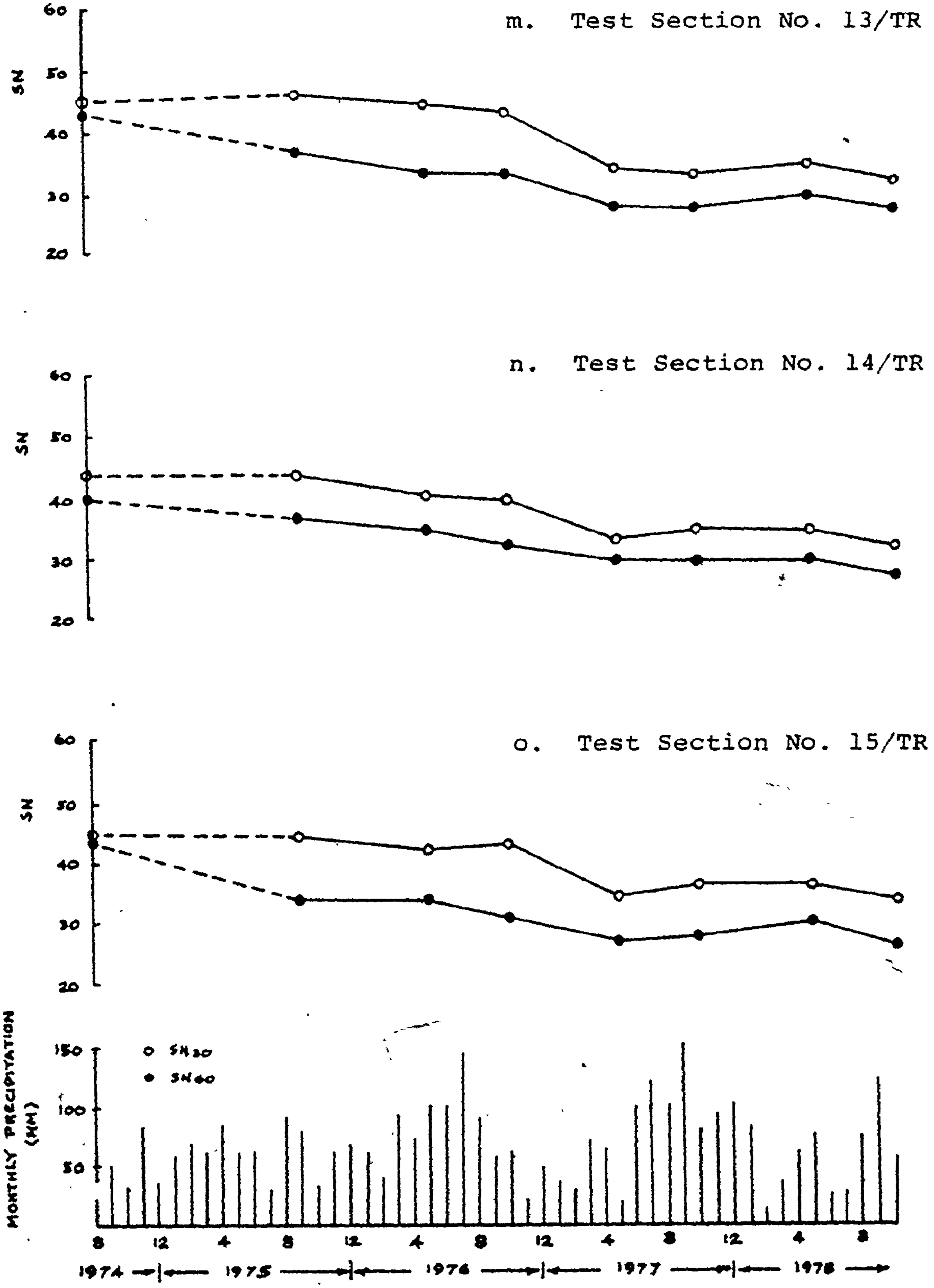
h. Test Section No. 8/SS

i. Test Section No. 9/BFS


j. Test Section No. 10/BFS

k. Test Section No. 11/TR

l. Test Section No. 12/TR


m. Test Section No. 13/TR
n. Test Section No. 14/TR
o. Test Section No. 15/TR
SN
60
50
40
30
20
MONTHLY PRECIPITATION (MM)
150
100
50
○ SN30
● SN60
8
12
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12
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1974
1975
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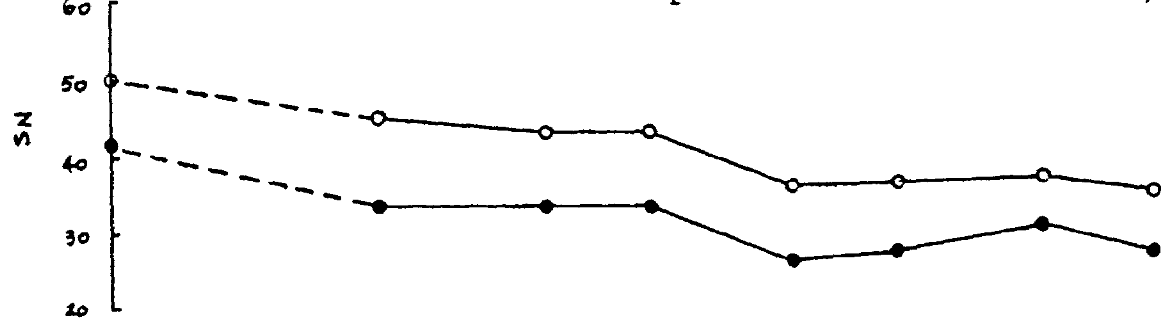
1977
1978

p. Test Section No. 16/TR



q. Test Section No. 17/TR

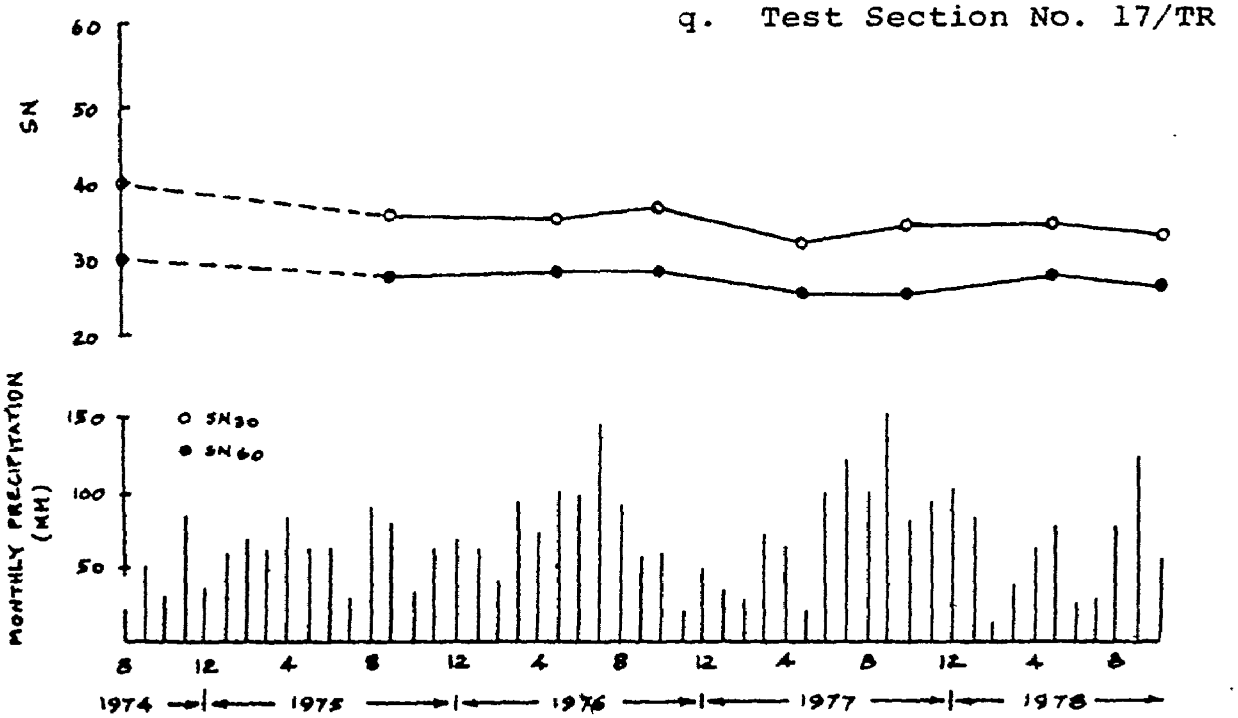
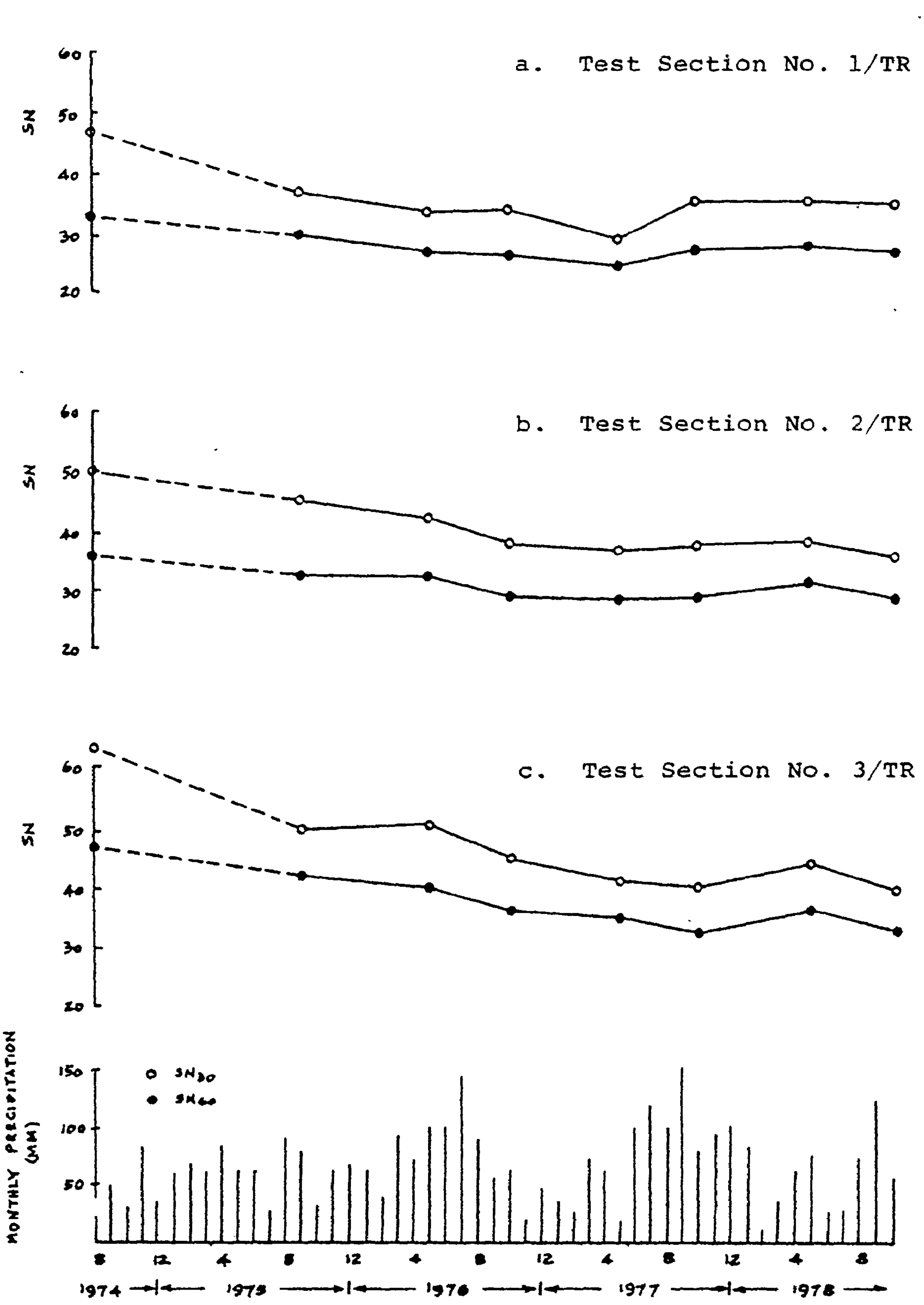


Figure C-3. Weathering Influences on Highway 401
Test Sections : Passing Lane

Note:

Precipitation readings were obtained from Downsview Airport, which is the closest Meterological Station to the test sections (23).


a. Test Section No. 1/TR
b. Test Section No. 2/TR
c. Test Section No. 3/TR
SN
60
50
40
30
20
MONTHLY PRECIPITATION (MM)
150
100
50
○ SN_{30}
● SN_{60}
8
12
4
8
12
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8
1974
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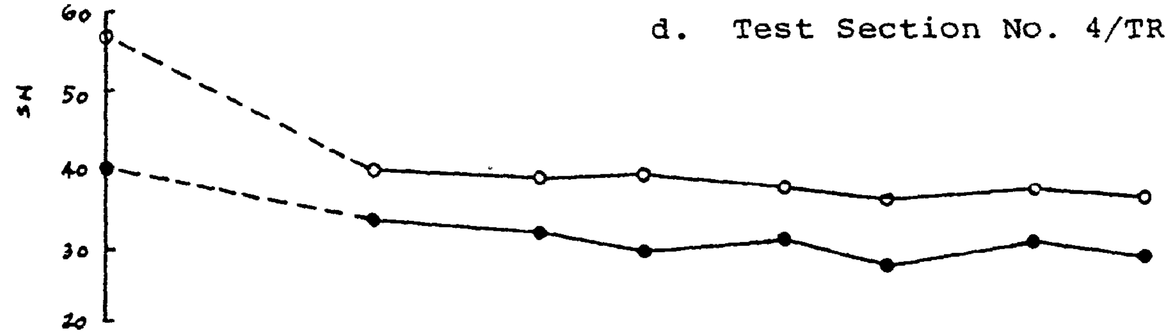
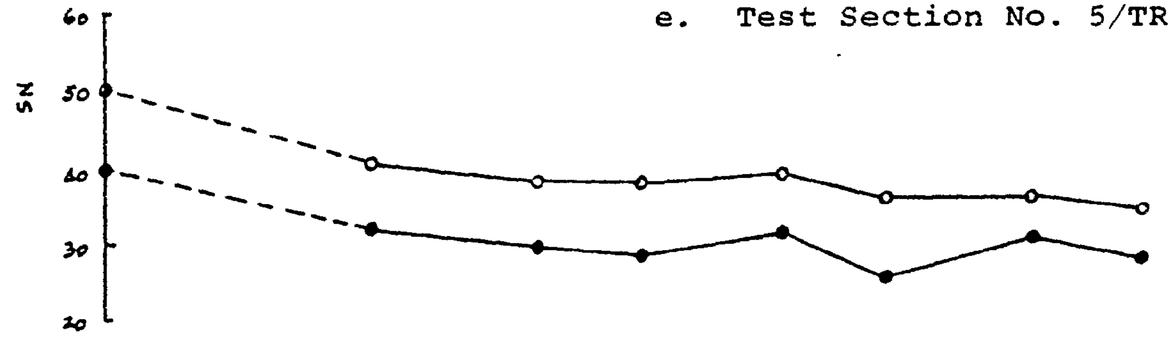
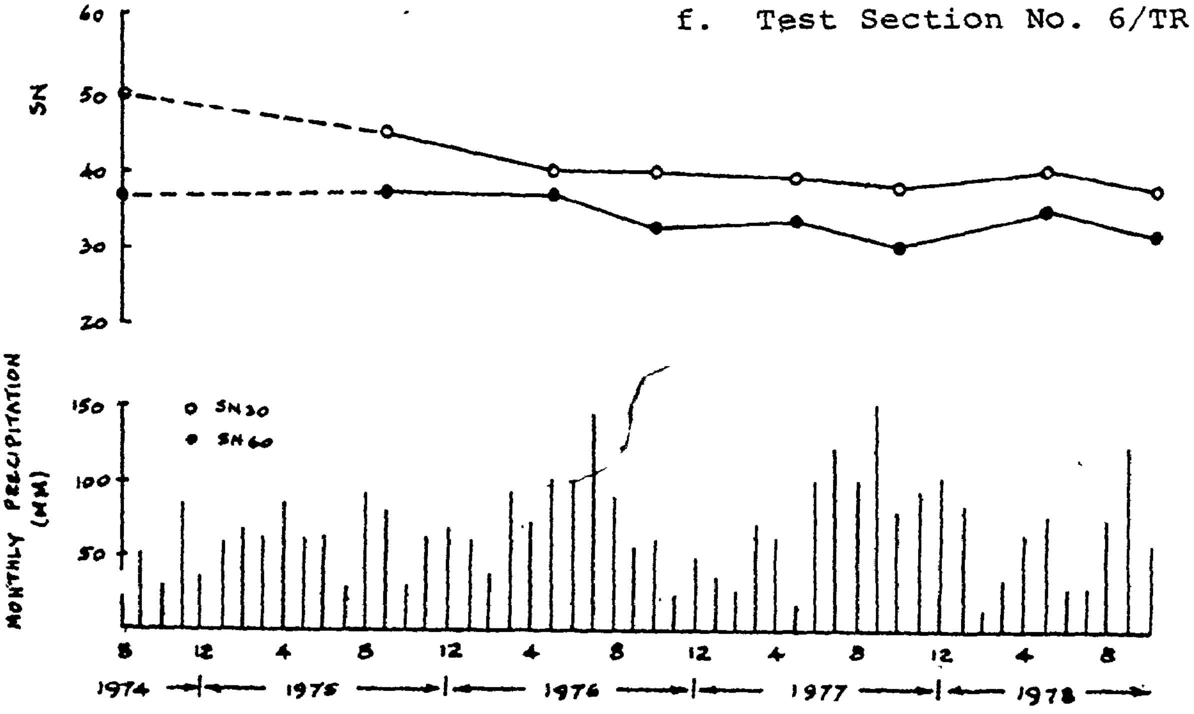
1977
1978



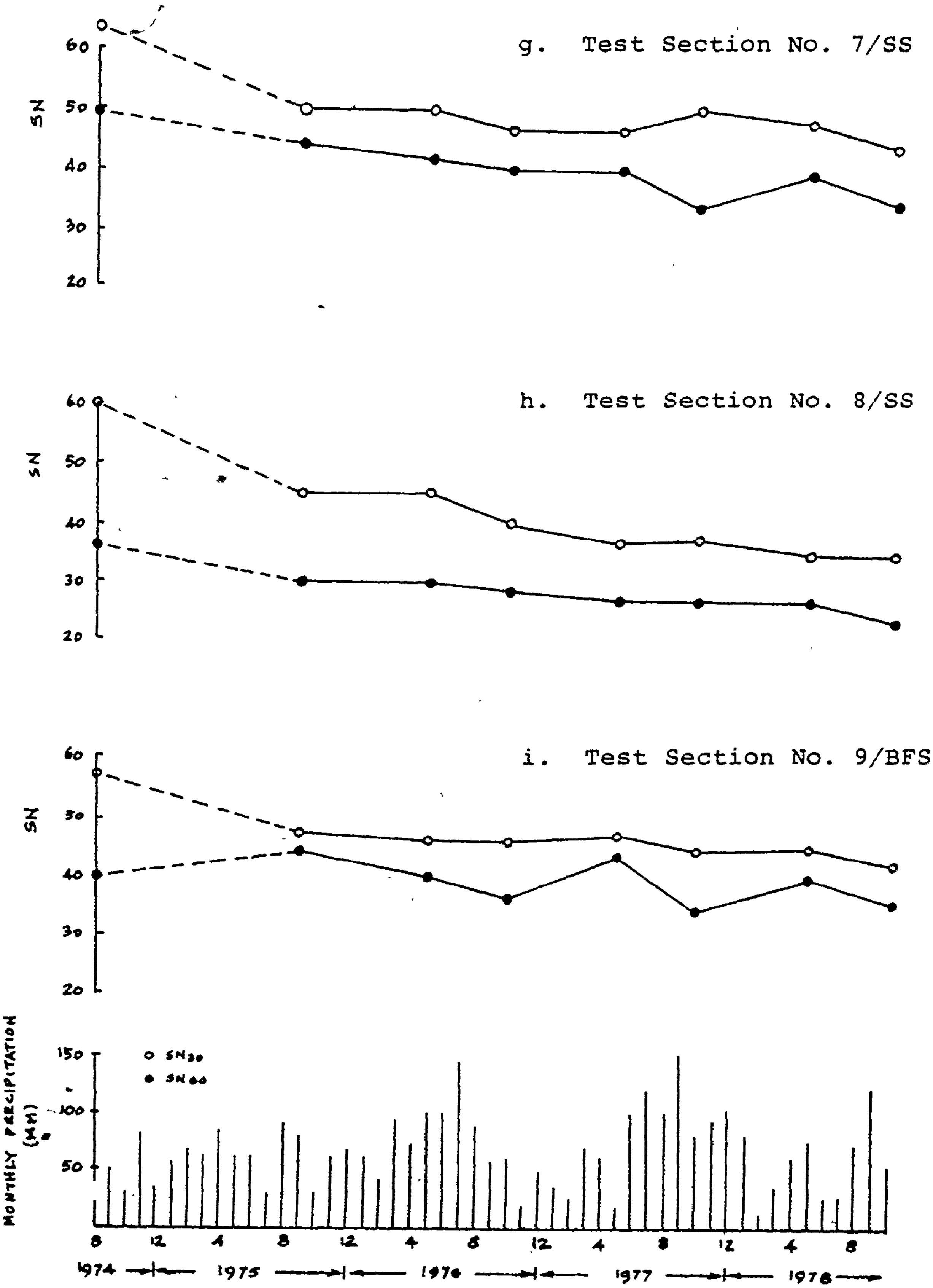
d. Test Section No. 4/TR



e. Test Section No. 5/TR



f. Test Section No. 6/TR

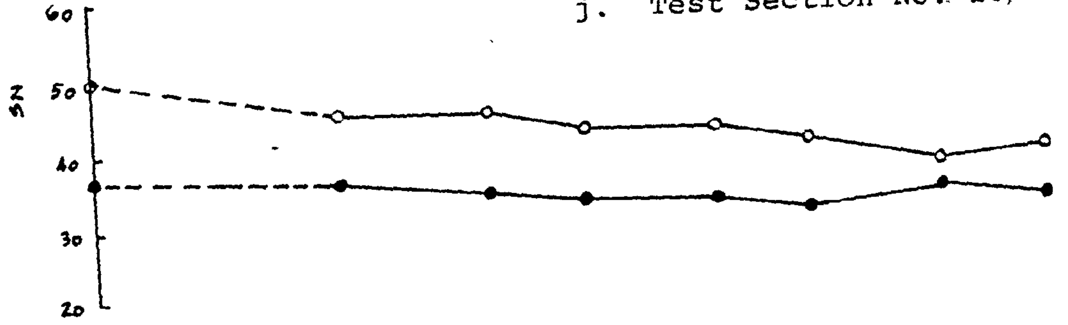


g. Test Section No. 7/SS

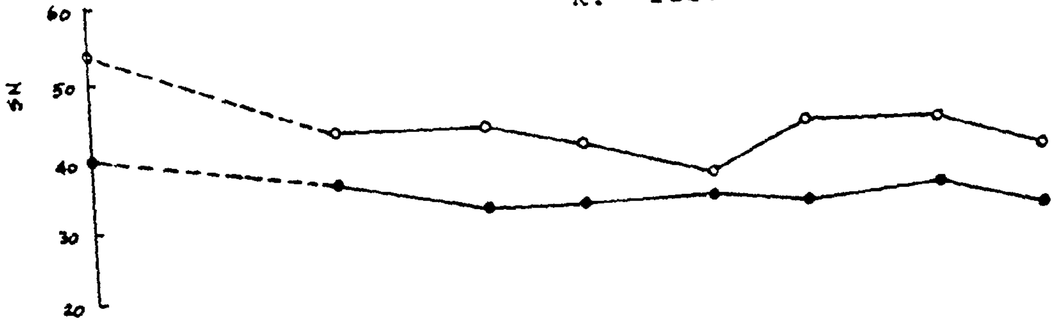
h. Test Section No. 8/SS

i. Test Section No. 9/BFS

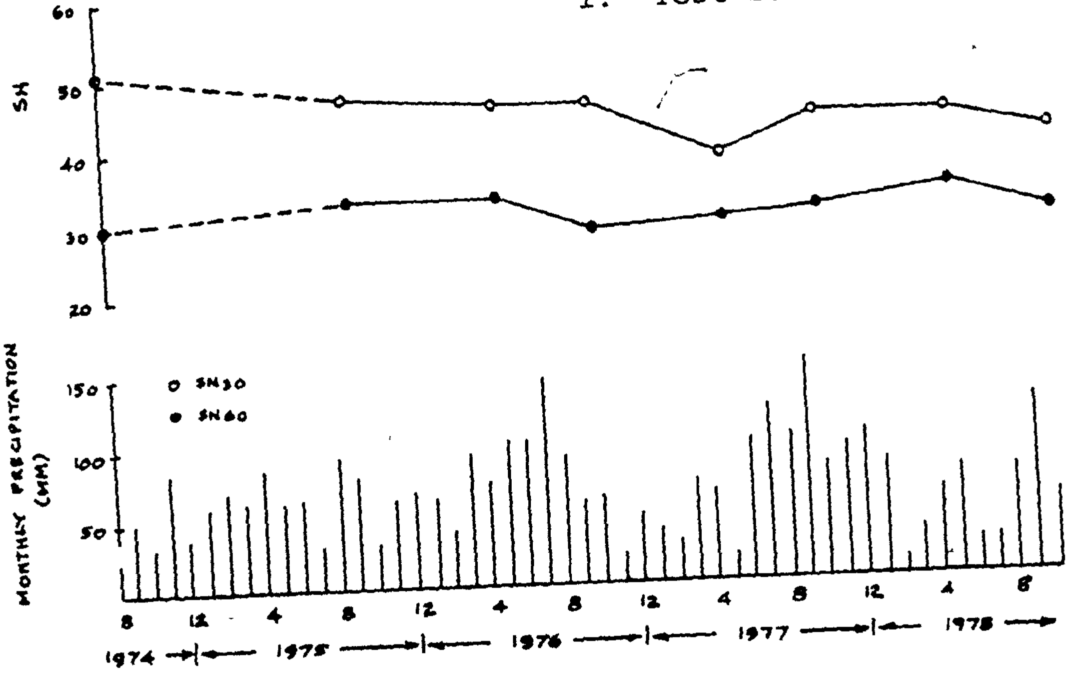
j. Test Section No. 10/BFS



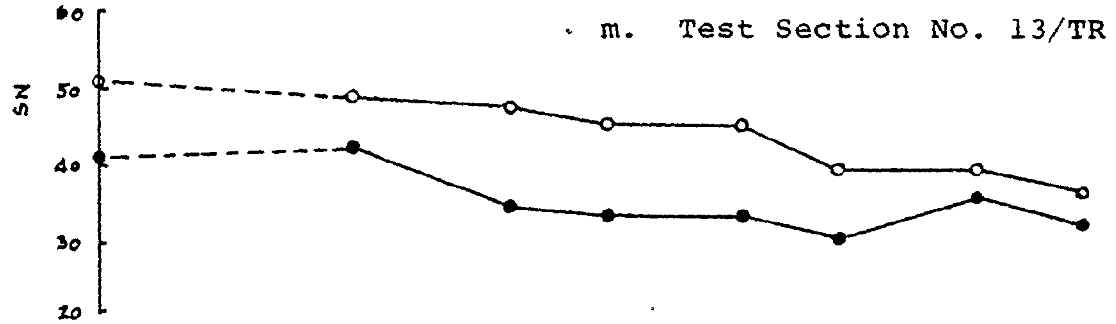
k. Test Section No. 11/TR



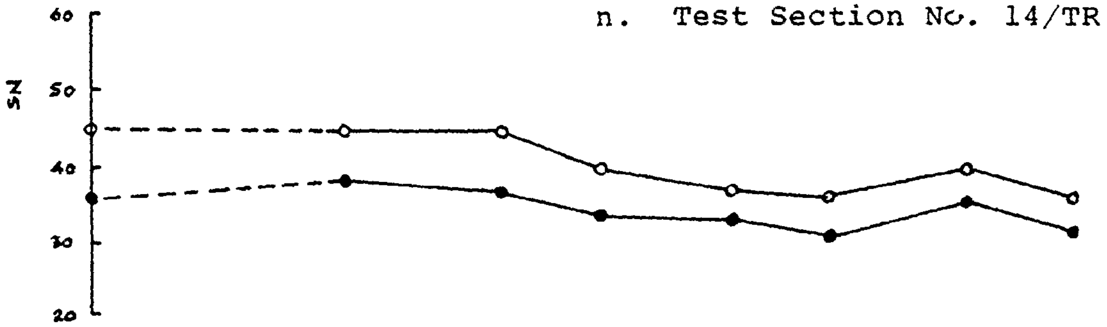
l. Test Section No. 12/TR



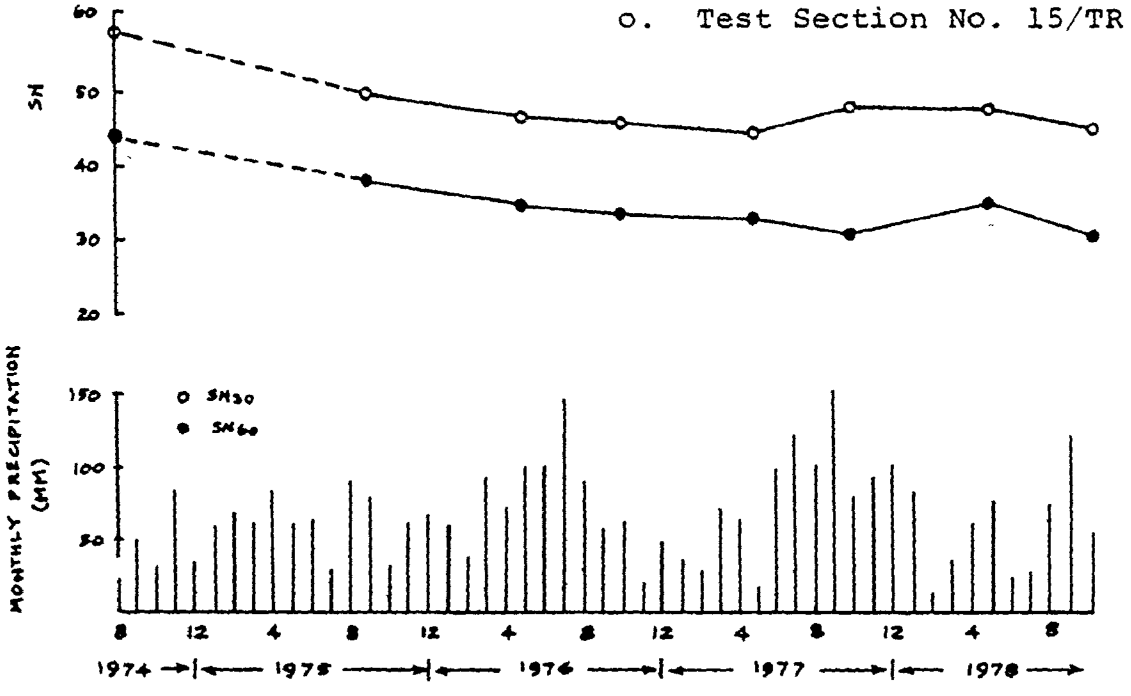
m. Test Section No. 13/TR



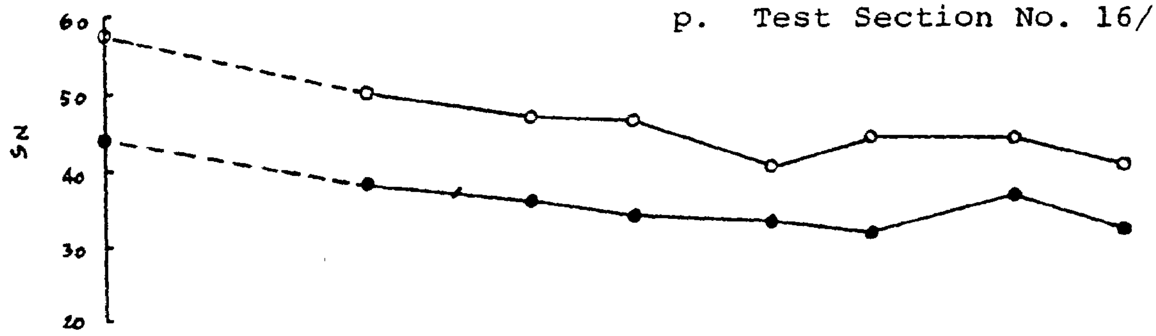
n. Test Section No. 14/TR



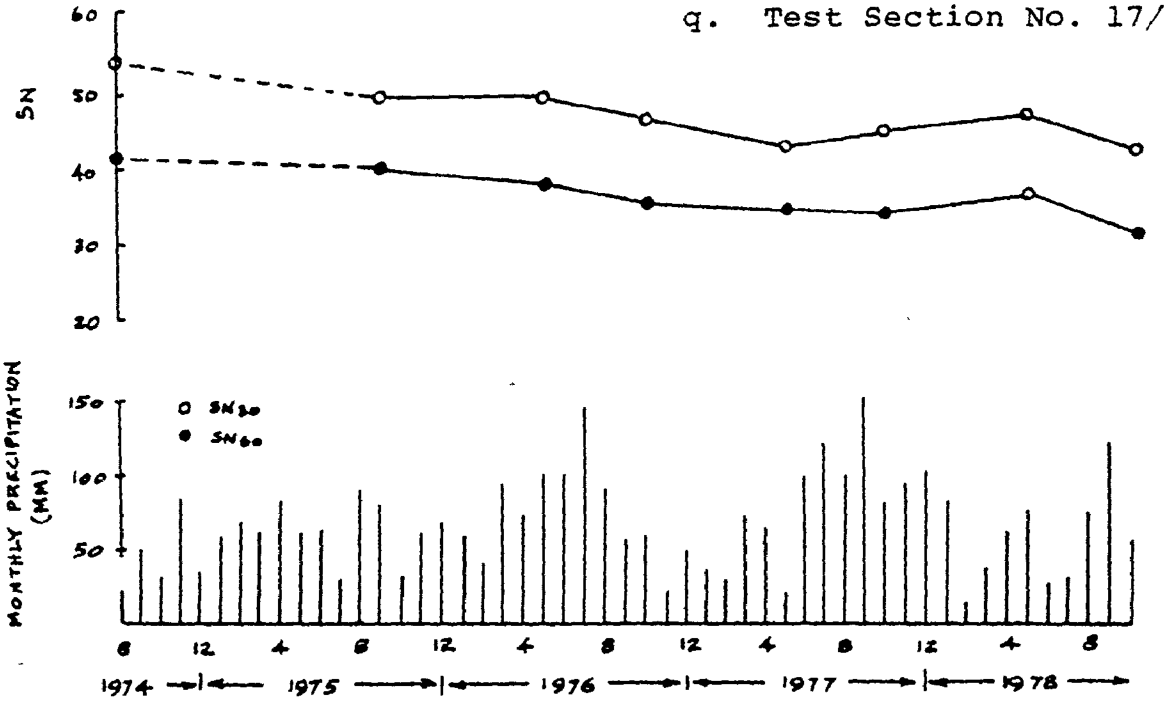
o. Test Section No. 15/TR



p. Test Section No. 16/TR



q. Test Section No. 17/TR



APPENDIX D :

INTERPRETATION OF XRD ANALYSES OF AGGREGATE WEATHERING

D.1 ANALYSIS PROCEDURE

There were four types of coarse aggregate analyzed by the x-ray diffraction method:

a. traprock;

b. limestone;

c. Dofasco steel slag; and

d. blast furnace slag

These aggregates were polished using the British Polishing Machine (BS 812, reference 6); some are analyzed after polishing, and the other subjected to artificial weathering in:

a. distilled water;

b. rainfall water;

c. synthetic rain; and

d. 1% by weight $CaCl_2$ solution.

The synthetic rain composition is given in Chapter 3.6.2. Chemical analyses for all of these solutions are provided in Appendix I.

The aggregates were subjected to simulated weathering for a period of 6 days, 15 days or both. After the simulated weathering, they were examined using the scanning electron microscope (Cambridge stereoscan SEM). The overall results are given in Chapter 3.

During this period, these aggregates were also examined for chemical elements, especially any contaminants or crystals developed during the process of weathering. This was done by the x-ray diffraction method (XRD).

The results of these analyses are given in the following sections.

D.2 SUMMARY TABLES

The results of the XRD analysis are given in Tables D-1 to D-4. The explanation of the Table entry numbers is as follows:

Example : W1D1/700/TA - 1

W : weathering process, all entries start with this letter

0/6/1 : Days in solution

0 = 0 days in solution (i.e. not weathered)

6 = 6 days in solution

1 = 15 days in solution (first digit only)

D/R/A/C : Type of solution

D = distilled water

R = rainfall water

A = synthetic rain

C = $CaCl_2$ solution

(for 0 days, no entry)

1/3/5/7 : Type of aggregate

1 = traprock

3 = limestone

5 = blast furnace slag

7 = Dofasco steel slag

700 : magnification on the SEM during the XRD analysis

(700 means that the sample was magnified 700X prior to the analysis)

TA/AR/SP : mode of analysis

TA : Total area (analysis on the total area for given magnification)

AR : Area (analysis on part of the area for the given magnification)

SP : Spot analysis, only one small area (dot) which is analyzed

1 : entry number (number of the analysis)

Table D-1. XRD Analyses for Traprock

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS															
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others	
Polished, No Weathering :		CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED												
surface characteristic	W01/580/TA-1								✓					✓	✓		
	W01/58/TA-2							✓	✓			✓		✓	✓		
Polished, 6 days in distilled water :																	
surface characteristic	W6D1/1350/TA-1							✓	✓						✓		
contamminants	W6D1/1350/SP-2							✓	✓						✓		
	W6D1/1350/SP-3								✓						✓		
	W6D1/1350/SP-4							✓	✓					✓	✓		
	W6D1/1350/AR-5							✓	✓				✓	✓			
Polished, 15 days in distilled water :																	
contaminants	W1D1/1800/SP-1					✓		✓	✓			✓		✓	✓		
	W1D1/1800/SP-2					✓	✓		✓			✓		✓	✓	Mn	
	W1D1/1800/SP-3						✓		✓					✓	✓		
	W1D1/1800/SP-4						✓		✓					✓	✓		
	W1D1/900/SP-5						✓		✓					✓	✓		
	W1D1/900/SP-6						✓		✓					✓	✓		
	W1D1/880/SP-7														✓		
	W1D1/880/SP-8						✓		✓					✓	✓		
	W1D1/1700/SP-9						✓	✓	✓			✓		✓	✓		
	W1D1/1700/SP 10										✓				✓		
Polished, 15 days in rainfall water :																	
surface characteristic	W1R1/64/TA-1							✓	✓					✓	✓		
	W1R1/1280/TA-2						✓		✓					✓	✓		
	W1R1/2520/TA-3						✓		✓					✓	✓		
Polished, 15 days in synthetic rain.																	
contaminants	W1A1/2800/AR-1								✓					✓	✓		
	W1A1/2800/SP-2								✓					✓	✓		
	W1A1/3150/SP-3							✓	✓					✓	✓		
	W1A1/3150/SP-4							✓	✓						✓		
Polished, 15 days in $CaCl_2$ solution																	
contaminants	W1C1/630/AR-1							✓	✓					✓	✓		
	W1C1/630/SP-2							✓	✓					✓	✓		

(continued)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS															
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others	
	WICI/1260/SP-3	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED			✓	✓						✓		
	WICI/2520/SP-4							✓	✓					✓	✓		
	WICI/2520/SP-5							✓	✓					✓	✓		
	WICI/2520/SP-6							✓	✓					✓	✓		

Table D-2. XRD Analyses for Limestone

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS															
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others	
Polished, No weathering		CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED												
surface characteristics	WO3/64/TA-1							✓	✓					✓			
	WO3/1240/TA-2							✓	✓					✓			
Polished, 15 days in distilled water																	
surface characteristic	WID3/1300/TA-1						✓							✓	✓		
	WID3/2600/TA-2						✓							✓	✓		
	WID3/640/TA-3						✓							✓	✓		
	WID3/1290/TA-4						✓							✓	✓		
	WID3/1300/AR-5						✓							✓	✓		
	WID3/2600/SP-6						✓							✓	✓		
	WID3/1300/SP-7						✓							✓	✓		
Polished, 15 days in rainfall water																	
surface characteristic	WIR3/1100/TA-1						✓							✓			
	WIR3/2100/TA-2						✓							✓			
	WIR3/1100/SP-3						✓							✓			
	WIR3/1100/SP-4						✓							✓			
	WIR3/2100/SP-5						✓							✓			
	WIR3/2100/SP-6						✓							✓			
Polished, 15 days in synthetic rain																	
surface characteristic	WIA3/250/TA-1						✓							✓			
	WIA3/1260/TA-2						✓							✓			
contaminants	WIA3/250/SP-1						✓							✓	✓		
	WIA3/250/SP-2								✓				✓	✓			
	WIA3/1260/AR-3						✓							✓			
	WIA3/1260/SP-4						✓		✓					✓			
	WIA3/1260/SP-5						✓							✓			
	WIA3/2500/SP-6						✓							✓			
	WIA3/2500/SP-7						✓							✓			
	WIA3/2500/SP-8						✓							✓			
	WIA3/2500/SP-9						✓							✓			
Polished, 15 days in $Cacl_2$ solution																	
surface characteristic	WIC3/2400/AR-1							✓	✓				✓	✓			

(continued)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS															
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others	
contaminants	WIC3/2400/SP-2	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED		✓	✓						✓			
	WIC3/2400/SP-3						✓	✓	✓				✓	✓			
	WIC3/1200/SP-4						✓							✓			
	WIC3/1200/SP-5							✓						✓	✓		

Table D-3. XRD Analyses for
Dofasco Steel Slag

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS														
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others	
Polished, No weathering		CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED												
surface characteristic	W07/2390/TA-1							✓	✓					✓	✓	Mn	
	W07/2390/SP-2							✓	✓					✓	✓	Mn	
	W07/2390/SP-3						✓	✓	✓					✓	✓	Mn	
	W07/2390/SP-4						✓		✓					✓	✓	Mn	
	W07/2390/SP-5													✓	✓	Mn	
Polished, 6 days in distilled water:																	
surface characteristic:	W6D7/1930/TA-1													✓	✓	Mn	
	W6D7/1930/SP-2													✓	✓	Mn	
	W6D7/1930/AR-3						✓							✓	✓	Mn	
	W6D7/2070/SP-4							✓						✓	✓		
contaminants	W6D7/2040/SP-5													✓	✓		
	W6D7/2040/SP-6													✓	✓		
	W6D7/2040/AR-7													✓	✓		
Polished, 15 days in distilled water:																	
surface characteristic	W1D7/280/TA-1							✓						✓	✓	Mn	
	W1D7/1600/TA-2							✓						✓	✓	Mn	
contaminants	W1D7/2800/SP-3							✓						✓	✓		
	W1D7/2800/SP-4													✓	✓		
	W1D7/1400/SP-5						✓							✓	✓	Mn	
	W1D7/1400/AR-6							✓	✓					✓	✓	Mn	
Polished, 15 days in rainfall water:																	
surface characteristic	W1R7/1300/TA-1							✓	✓					✓	✓	Mn	
	W1R7/1300/SP-2							✓	✓					✓	✓	Mn	
contaminants	W1R7/2600/SP-3													✓	✓	Mn	
	W1R7/2600/SP-4								✓					✓	✓		
	W1R7/650/SP-5						✓		✓					✓	✓	Mn	
	W1R7/1300/SP-6													✓	✓	Mn	
Polished, 15 days in synthetic rain:																	
surface characteristic	W1A7/600/TA-1								✓						✓		
contaminants	W1A7/600/SP-2								✓						✓		
	W1A7/2350/SP-3							✓							✓		

(continued)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS															
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others	
	WIA7/2350/AR-4	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED			✓	✓						✓		
	WIA7/2360/SP-5							✓	✓					✓	✓		
	WIA7/2360/SP-6							✓	✓					✓	✓		
	WIA7/2360/SP-7								✓						✓		
	WIA7/580/SP-8														✓		
	WIA7/1160/SP-9								✓						✓		
	WIA7/1160/SP10							✓	✓						✓		
Polished, 15 days in $CaCl_2$ solution																	
surface characteristic	WIC7/64/TA-1							✓						✓	✓	Mn	
	WIC7/650/TA-2							✓						✓	✓	Mn	
contaminants	WIC7/650/SP-3							✓						✓	✓	Mn	
	WIC7/1300/SP-4								✓						✓	Mn	
	WIC7/1300/SP-5													✓			

Table D-4. XRD Analyses for Blast Furnace Slag

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS															
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others	
Polished, No weathering		CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED												
surface characteristic	W05/2700/TA-1							✓						✓			
	W05/67/TA-2							✓						✓			
Polished, 6 days in distilled water																	
surface characteristic	W6DS/2600/TA-1							✓						✓			
	W6DS/2700/TA-2							✓	✓					✓			
contaminants	W6DS/2600/SP-3							✓									
	W6DS/2600/SP-4							✓									
	W6DS/2700/SP-5							✓						✓			
	W6DS/2700/SP-6							✓									
	W6DS/2700/SP-7							✓									
Polished, 15 days in distilled water:																	
surface characteristic	W1DS/2320/TA-1						✓	✓	✓					✓	✓		
contaminants	W1DS/2320/SP-2							✓	✓					✓	✓		
	W1DS/1160/SP-3										✓	✓			✓		
	W1DS/1160/SP-4							✓						✓	✓		
	W1DS/1160/SP-5							✓	✓				✓	✓	✓		
	W1DS/1160/SP-6							✓	✓			✓		✓	✓		
	W1DS/1160/SP-7							✓	✓					✓	✓	Mn	
	W1DS/1150/SP-8							✓						✓	✓		
	W1DS/1150/SP-9							✓				✓		✓	✓		
Polished, 15 days in rainfall water:																	
surface characteristic	W1RS/1340/SP-1							✓									
	W1RS/1340/AR-2							✓						✓			
	W1RS/2680/AR-3								✓					✓			
contaminants	W1RS/1340/SP-4							✓								Zn	
	W1RS/1340/SP-5							✓			✓			✓		Zn	
	W1RS/2680/SP-6										✓					Zn	
Polished, 15 days in synthetic rain:																	
surface characteristic	W1AS/550/TA-1							✓	✓						✓		
	W1AS/550/AR-2							✓	✓						✓		
contaminants	W1AS/1100/SP-3							✓	✓					✓			

(continued)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS														
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others
	WIAS/1100/SP-4	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED			✓	✓					✓		
Polished, 15 days in $CaCl_2$ solution.																
surface characteristic	WICS/232/TA-1								✓					✓		
	WICS/232/AR-2							✓	✓					✓		
	WICS/1160/AR-3							✓	✓					✓		
contaminants	WICS/232/SP-4							✓						✓		
	WICS/232/SP-5							✓							✓	
	WICS/232/SP-6							✓	✓					✓		
	WICS/232/SP-7							✓	✓						✓	
	WICS/2330/SP-8								✓					✓		
	WICS/2330/SP-9						✓	✓	✓					✓		
	WICS/2330/SP-10							✓	✓					✓		

The list of most possible elements are summarized from the complete listings of XRD analysis given in section D.4. Gold and Paladium, which is the main content of the coating, are not included in these tables.

D.3 CHEMICAL ELEMENT STATISTICS OF XRD ANALYSES

Final graphs, which summarize the findings obtained in Tables D-1 to D-4 are given in Figures D-1 to Figures D-4.

D.4 COMPLETE LISTING OF THE XRD ANALYSES

A complete listing of the XRD analysis as summarized in Tables D-1 to D-4 and Figures D-1 to D-4 were given in Tables D-5. They contain the output analyses provided by the analyzer. The centroid readings indicate the x-ray emission energies. From the Table A-1, one can analyze the elements of the surface of crystal/contaminant. Some small adjustments are necessary to obtain the right element. These were done based on the Gold/Paladium reading which exists due to the coating applied on the aggregates.

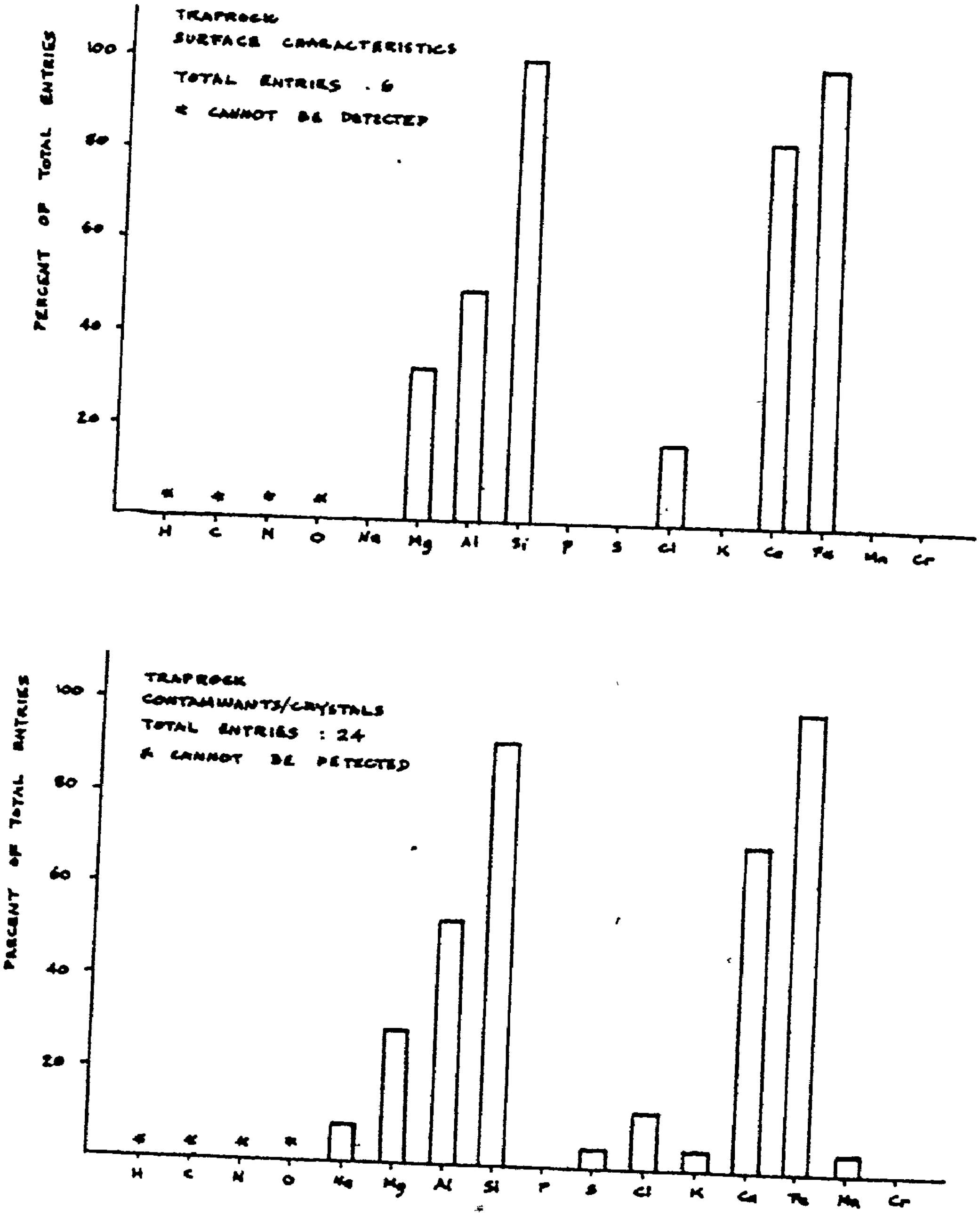


Figure D-1. Chemical Element Statistics for Traprock

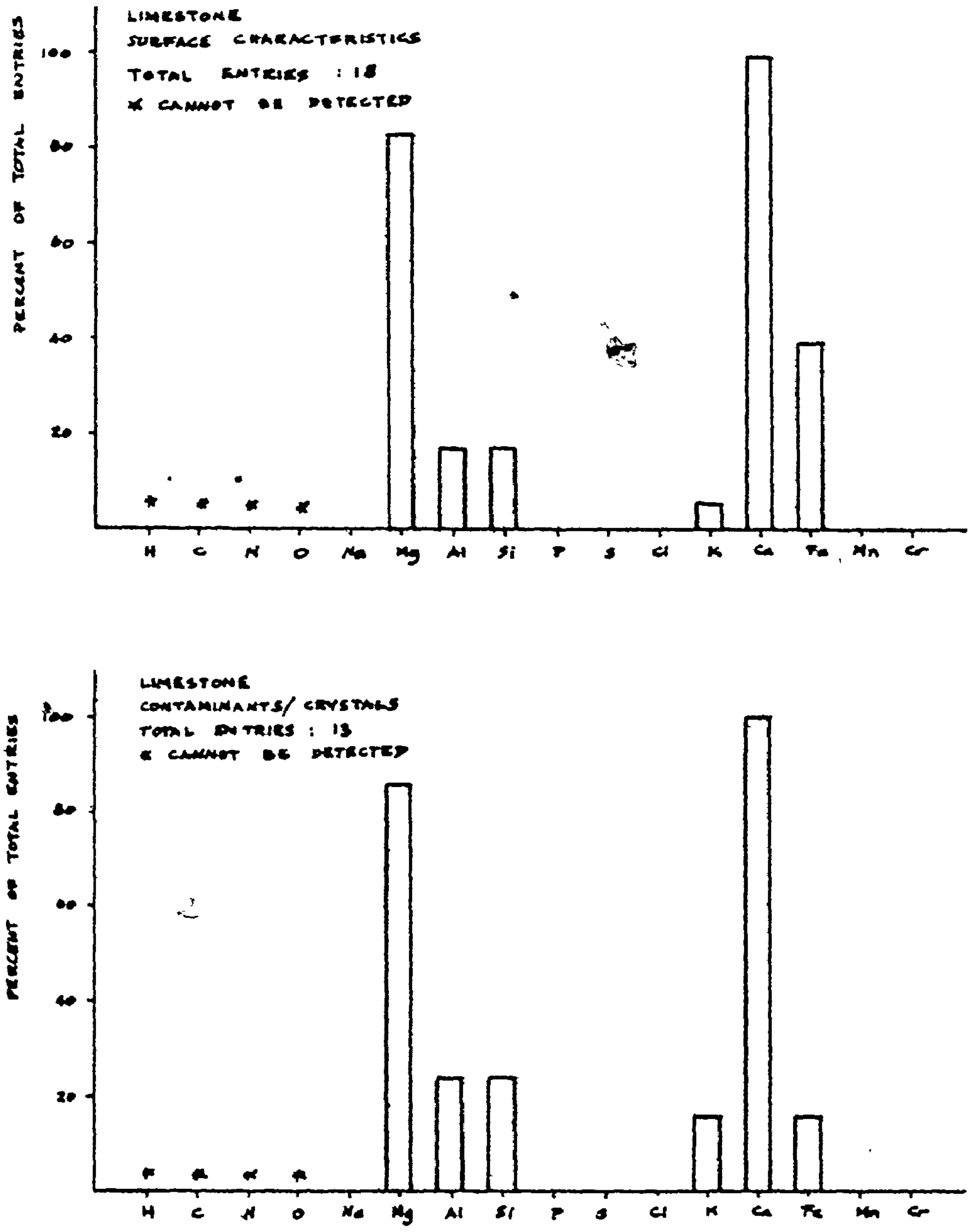


Figure D-2. Chemical Element Statistics for Limestone

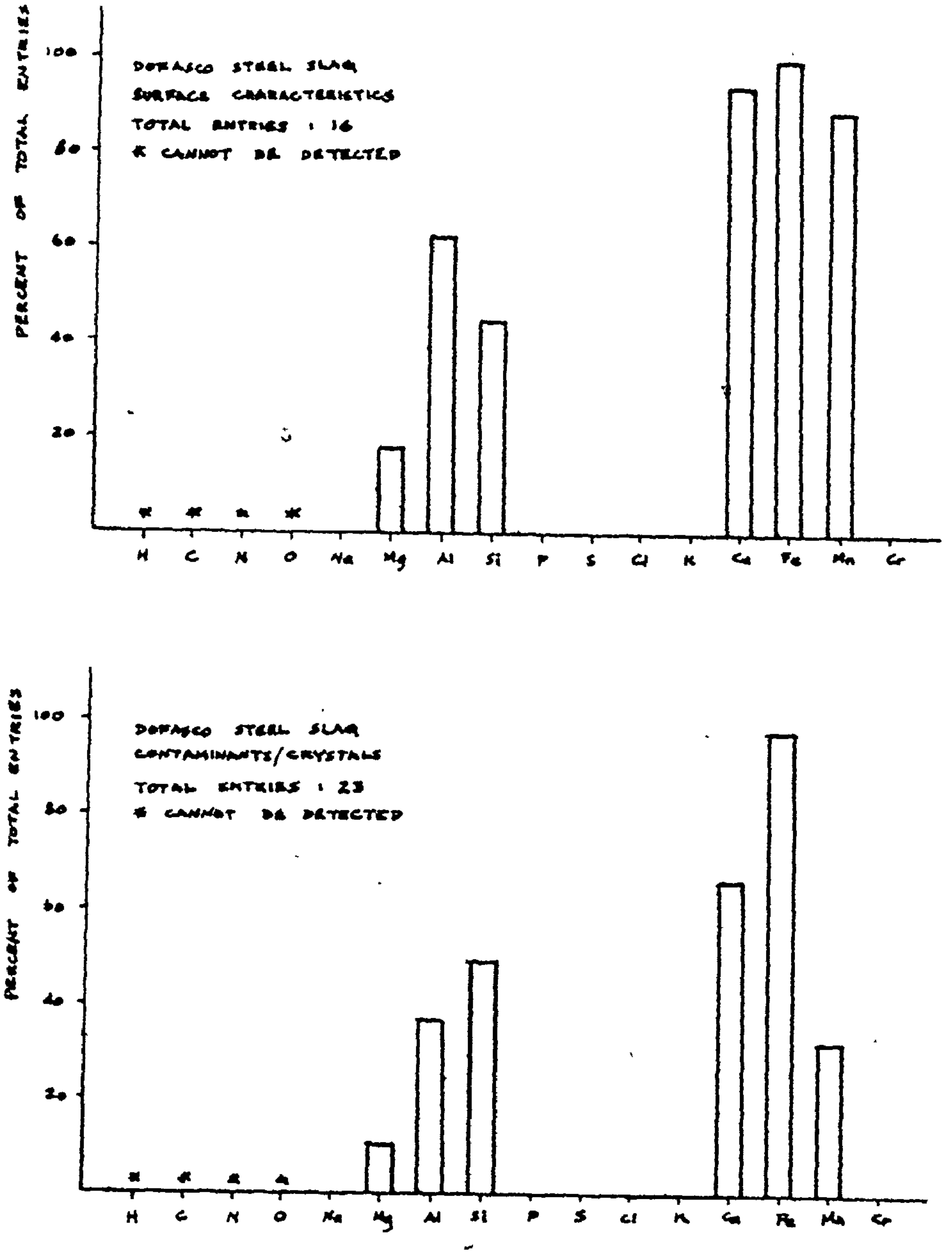


Figure D-3. Chemical Element Statistics for Dofasco Steel Slag

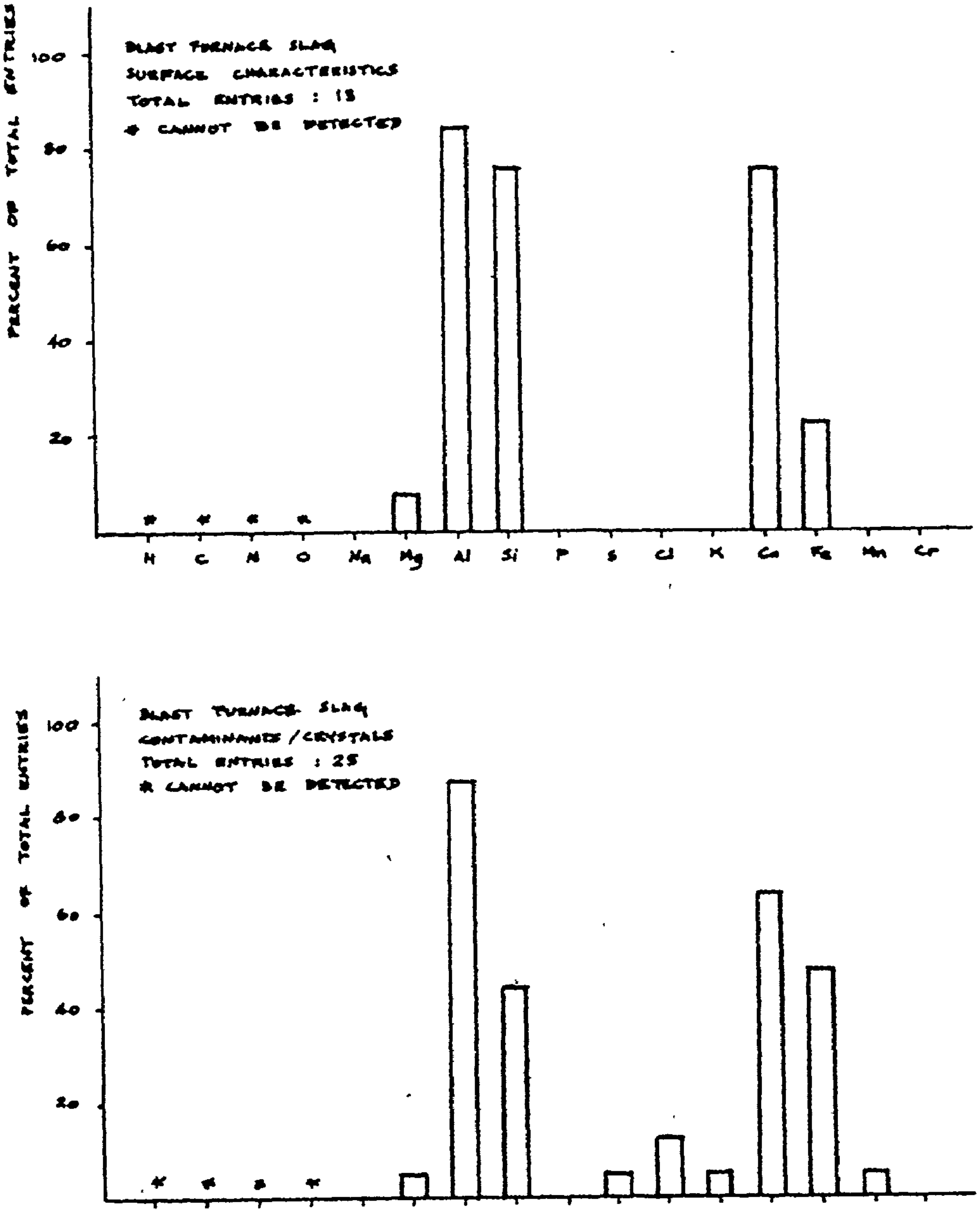


Figure D-4. Chemical Element Statistics for Blast Furnace Slag

Table D-5. Complete Listing of XRD Analyses of Aggregate Weathering

W01/580/TA-1

centroid adjustment : + 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.73	Si	0.14	1781.20	73	94
2	1	2.15	—	0.14	3757.96	106	127
3	1	3.68	Ca	0.15	748.47	226	247
4	1	6.39	Fe	0.13	1000.98	439	460
5	1	9.69	—	0.16	793.46	698	718

W01/58/TA-2

centroid adjustment : + 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.45	Al	0.06	817.75	56	68
2	1	1.72	Si	0.16	1333.21	73	94
3	1	2.14	—	0.16	3288.34	106	126
4		2.61	Cl	0.09	238.10	144	162
5	1	3.67	Ca	0.15	1403.91	226	246
6	1	6.40	Fe	0.15	1115.98	440	460
7	1	9.69	—	0.14	433.73	697	718
8	1	11.41	—	0.10	61.53	832	853

W6P1/1350/TA-1

centroid adjustment : + 0.32

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.17	Al	0.07	233.00	30	50
2	1	1.43	Si	0.13	650.16	50	70
3	1	1.63	—	0.15	743.66	82	102
4	1	6.09	Fe	0.13	3071.09	416	436
5	1	6.75	Fe	0.15	363.54	467	467
6	1	9.42	—	0.14	573.95	677	696

W6P1/1350/SP-2

centroid adjustment : + 0.33

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.16	Al	0.06	458.02	30	47
2	1	1.48	Si	0.10	609.73	49	70
3	1	1.63	—	0.15	2470.21	61	102
4	1	6.09	Fe	0.14	4193.46	415	436
5	1	6.73	Fe	0.12	740.42	466	466
6	1	9.40	—	0.14	644.98	675	696

W6P1/1350/SP-3

centroid adjustment : + 0.32

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.42	Si	0.12	522.22	49	70
2	1	1.84	—	0.14	1066.23	62	103
3	1	6.09	Fe	0.15	3831.46	416	436
4	1	6.74	Fe	0.13	607.46	466	466
5	1	9.41	—	0.13	539.74	676	696
6	1	11.19	—	0.07	331.6	616	636

W6P1/1350/SP-4

centroid adjustment : + 0.32

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.16	Al	0.06	207.76	28	49
2		1.42	Si	0.10	426.25	51	68
3	1	1.64	—	0.15	913.72	62	103
4	1	6.09	Ca	0.15	4944.95	415	436
5	1	6.74	Fe	0.13	773.47	466	487
6	1	9.39	—	0.14	660.75	675	695

W6P1/1350/AR-5

centroid adjustment : + 0.32

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.16	Al	0.06	201.76	26	49
2	1	1.42	Si	0.10	1044.06	49	69
3	1	1.62	—	0.12	1216.11	61	101
4		3.01	K	0.02	29.13	178	190
5	1	6.09	Fe	0.14	3439.33	416	436
6	1	6.75	Fe	0.17	465.66	466	466
7	1	9.40	—	0.19	771.75	675	696

W1B1/900/SP-5

centroid adjustment : + 0.0

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.26	Mg	0.10	615.54	37	57
2	1	1.75	Si	0.12	3127.73	75	96
3	1	2.16	—	0.14	3531.20	107	126
4	1	3.71	Ca	0.12	1077.96	229	249
5	1	6.41	Fe	0.05	317.71	441	462
6	1	9.66	—	0.13	240.53	696	717

(continued)

WIDI/1800/SP-1

centroid adjustment : + 0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.05	Na	0.14	414.80	20	41
2	1	1.46	Al	0.10	701.04	54	75
3	1	1.74	Si	0.12	3464.96	75	95
4	1	2.15	—	0.13	2279.27	106	127
5	1	2.64	Cl	0.12	149.25	146	166
6	1	3.69	Ca	0.03	239.16	226	246
7	1	3.70	Ca	0.03	273.70	228	249
8	1	6.40	Fe	0.07	316.23	440	460
9	1	9.73	—	0.05	62.98	701	722

WIDI/1800/SP-2

centroid adjustment : +0.0

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	0.99	Na	0.03	59.41	21	41
2		1.26	Mg	0.08	257.75	39	55
3	1	1.75	Si	0.12	2475.95	75	96
4	1	2.16	—	0.14	2358.97	107	128
5	1	2.64	Cl	0.11	614.56	145	165
6	1	3.70	Ca	0.15	990.50	228	249
7	1	6.41	Fe	0.09	252.61	440	460
8	1	6.44	Mn	0.13	325.24	444	464

WIDI/1800/SP-3

centroid adjustment : +0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.27	Mg	0.03	146.13	44	52
2	1	1.75	Si	0.12	2069.73	75	96
3	1	2.15	—	0.15	3624.97	107	127
4	1	3.70	Ca	0.14	559.38	228	248
5	1	6.42	Fe	0.01	299.60	441	461
6	1	9.71	—	0.08	200.63	699	719
7	1	9.72	—	0.07	155.49	701	721

WIDI/1800/SP-4

centroid adjustment : + 0.0

NC.	ECL	CENTROID		FWHM	AREA	LEFT	HIGHT
1		1.26	Mg	0.09	277.17	37	57
2	1	1.59	—	0.01	-70.96	55	76
3	1	1.74	Si	0.12	2067.47	74	95
4	1	2.16	—	0.14	2807.24	107	128
5	1	2.74	—	0.03	-12.74	145	165
6	1	3.70	Ca	0.11	436.45	228	249
7	1	6.41	Fe	0.14	1418.99	441	461
8	1	7.05	Fe	0.09	91.30	491	512
9	1	7.09	Fe	0.07	139.10	495	515
10	1	9.73	—	0.10	101.4	702	722

WIDI/900/SP-6

centroid adjustment : - 0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.26	Mg	0.10	472.03	36	56
2	1	1.62	—	0.03	-60.50	55	75
3	1	1.75	Si	0.12	3864.97	75	96
4	1	2.17	—	0.14	2057.85	106	126
5	1	3.71	Ca	0.13	908.46	226	249
6	1	6.41	Fe	0.12	576.00	440	461
7	1	7.06	Fe	0.06	81.99	493	514

WIDI/880/SP-7

centroid adjustment : +0.0

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.16	—	0.15	1973.95	107	128
2	1	6.41	Fe	0.14	2195.47	441	461
3	1	7.08	Fe	0.17	355.74	493	514
4	1	9.71	—	0.08	196.99	700	720

WIDI/880/SP-8

centroid adjustment : +0.0

NC.	ECL	CENTROID		FWHM	AREA	LEFT	HIGHT
1	1	1.26	Mg	0.09	682.03	37	58
2	1	1.75	Si	0.12	3732.21	75	96
3	1	2.16	—	0.14	2452.95	107	128
4	1	3.70	Ca	0.14	1524.74	226	249
5	1	6.41	Fe	0.15	302.30	440	461
6	1	11.49	—	0.01	86.84	636	656

(continued)

WIPI/1700/SP-9

centroid adjustment : +0.0

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.25 Mg	0.10	555.90	37	57
2	1	1.48 Al	0.09	372.67	55	75
3	1	1.75 Si	0.12	2175.73	75	96
4	1	2.16 —	0.15	2890.20	107	128
5	1	2.65 Cl	0.03	274.73	146	166
6	1	3.70 Ca	0.12	420.00	228	248
7	1	6.41 Fe	0.11	475.71	441	461
8	1	9.66 —	0.01	17.71	699	719

WIPI/1700/SP-10

centroid adjustment : +0.0

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	2.31 S	0.12	4010.22	119	140
2	1	6.41 Fe	0.16	2528.49	440	461
3	1	7.07 Fe	0.05	340.71	493	513

WIRI/64/TA-1

centroid adjustment : +0.0

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.46 Al	0.11	371.01	54	74
2	1	1.74 Si	0.14	2239.97	74	95
3	1	2.16 —	0.14	1002.23	107	128
4	1	3.70 Ca	0.15	1448.46	228	248
5	1	6.40 Fe	0.14	764.23	439	460
6		7.07 Fe	0.10	147.87	496	510

WIRI/1280/TA-2

centroid adjustment : +0.01

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.24 Mg	0.08	310.25	36	57
2	1	1.74 Si	0.11	3669.97	74	95
3	1	2.15 —	0.14	1682.24	107	127
4	1	3.69 Ca	0.13	1173.75	227	246
5	1	6.40 Fe	0.13	659.74	440	460
6	1	7.03 Fe	0.03	101.01	488	509
7	1	7.05 Fe	0.03	114.48	491	511
8	1	9.66 —	0.10	219.63	697	717

WIRI/2520/TA-3

centroid adjustment . +0.02

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1		1.24 Mg	0.09	364.15	36	54
2	1	1.74 Si	0.13	3066.97	74	95
3	1	2.14 —	0.14	1325.39	106	126
4	1	3.69 Ca	0.13	1047.20	227	246
5	1	6.39 Fe	0.10	845.21	440	460
6	1	7.06 Fe	0.05	157.23	490	511

WIAI/2000/AR-1

centroid adjustment : +0.04

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.71 Si	0.14	604.30	45	66
2	1	2.12 —	0.14	2097.77	76	98
3	1	3.66 Ca	0.13	1946.65	199	219
4	1	6.36 Fe	0.11	549.53	410	431
5	1	7.04 Fe	0.15	235.47	465	485
6	1	9.67 —	0.12	221.85	672	692

WIAI/2800/SP-2

centroid adjustment +0.04

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.69 Si	0.15	575.76	44	64
2	1	2.12 —	0.13	2800.79	77	96
3	1	3.66 Ca	0.14	2129.85	199	219
4	1	6.35 Fe	0.07	236.74	410	430
5	1	9.67 —	0.10	481.74	671	691

WIAI/3150/SP 3

centroid adjustment . +0.03

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.45 Al	0.12	311.51	25	46
2	1	1.70 Si	0.04	292.97	44	64
3	1	1.70 Si	0.04	340.50	46	66
4	1	2.13 —	0.13	2153.49	76	96
5	1	3.67 Ca	0.15	261.00	200	220
6	1	6.37 Fe	0.06	273.46	411	431
7	1	9.66 —	0.13	946.77	670	691

(continued)

WIA1/3150/SP-4
centroid adjustment : + 0.03

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.07	228.05	25	46
2	1	1.72	Si	0.02	58.38	43	63
3	1	2.13	—	0.16	2395.95	78	99
4		6.36	Fe	0.07	184.54	413	432
5	1	9.67	—	0.17	1109.49	671	692
6	1	11.37	—	0.02	-51.60	810	830

WIC1/630/AR-1
centroid adjustment : + 0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.46	Al	0.07	427.51	56	73
2	1	1.74	Si	0.12	2805.72	74	95
3	1	2.15	—	0.16	2139.95	106	127
4	1	3.69	Ca	0.04	542.70	227	248
5	1	4.52	—	0.02	315.23	292	313
6	1	6.40	Fe	0.14	1394.25	440	461
7	1	7.06	Fe	0.14	292.59	493	513
6	1	9.70	—	0.17	605.33	699	719

WIC1/630/SP-2
centroid adjustment : + 0.0

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.47	Al	0.13	222.28	54	75
2	1	1.75	Si	0.11	990.96	75	95
3	1	2.16	—	0.13	584.84	107	127
4	1	3.69	Ca	0.11	310.47	227	246
5	1	4.51	—	0.09	63.30	292	313
6	1	6.41	Fe	0.15	2190.24	440	461
7	1	7.05	Fe	0.02	164.00	490	511
8		7.09	Fe	0.13	252.86	497	511
9	1	9.71	—	0.04	328.96	700	720

WIC1/1260/SP-3
centroid adjustment : + 0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.06	630.53	53	74
2	1	1.74	Si	0.13	4636.22	74	95
3	1	2.15	—	0.15	4356.00	106	127
4	1	6.40	Fe	0.17	509.65	440	460
5	1	9.66	—	0.09	567.30	697	718

WIC1/2520/SP-4
centroid adjustment : + 0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.02	252.92	54	74
2	1	1.74	Si	0.12	2615.97	74	95
3	1	2.15	—	0.15	4567.46	106	127
4	1	3.70	Ca	0.06	100.22	229	250
5	1	6.39	Fe	0.11	646.50	439	460
6	1	9.69	—	0.14	542.22	696	719

WIC1/2520/SP-5
centroid adjustment : + 0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.45	Al	0.07	111.52	53	74
2	1	1.74	Si	0.12	2142.49	74	95
3	1	2.15	—	0.16	4123.23	106	127
4		3.71	Ca	0.10	184.50	231	247
5	1	6.40	Fe	0.12	825.20	440	461
6	1	9.66	—	0.02	256.36	694	714
7	1	9.70	—	0.21	597.72	699	719

WIC1/2520/SP-6
centroid adjustment : + 0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.47	Al	0.10	642.40	54	74
2	1	1.74	Si	0.12	2661.23	74	95
3	1	8.15	—	0.14	3226.72	106	127
4	1	3.69	Ca	0.13	829.00	227	247
5	1	6.40	Fe	0.14	1134.70	439	460
6	1	9.68	—	0.11	396.63	697	717

WOB/1240/TA-2
centroid adjustment : + 0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.04	210.27	54	74
2	1	1.74	Si	0.10	1611.70	74	95
3	1	2.15	—	0.17	2557.72	106	127
4	1	3.69	Ca	0.13	2227.61	226	246
5	1	9.66	—	0.12	315.47	697	716

(continued)

WD3/64/TA-1
centroid adjustment : + 0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.10	205.27	54	74
2	1	1.73	Si	0.10	1498.22	74	94
3	1	2.15	—	0.14	2899.99	106	127
4	1	3.69	Ca	0.11	1764.24	227	248
5		4.02	Ca	0.10	270.84	254	272
6	1	9.67	—	0.06	294.13	697	717
7	1	11.40	—	0.11	66.79	830	851

WID3/1300/TA-1
centroid adjustment : + 0.32

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	0.94	Mg	0.08	463.30	11	32
2	1	1.64	—	0.15	2137.97	62	102
3	1	3.38	Ca	0.13	3943.13	203	223
4	1	3.69	Ca	0.13	672.73	228	246
5	1	6.08	Fe	0.15	2543.99	415	436
6	1	6.75	Fe	0.13	396.70	467	466
7	1	9.40	—	0.19	452.70	675	696

WID3/2600/TA-2
centroid adjustment : + 0.32

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		0.93	Mg	0.07	263.26	11	32
2	1	1.64	—	0.13	1607.61	82	102
3	1	3.36	Ca	0.18	3160.66	203	223
4	1	6.09	Fe	0.13	1530.73	416	436
5	1	6.77	Fe	0.03	176.6	469	469
6	1	9.40	—	0.04	157.47	674	695

WID3/640/TA-3
centroid adjustment : + 0.32

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	0.92	Mg	0.12	240.04	12	32
2	1	1.64	—	0.13	1463.10	62	102
3	1	3.36	Ca	0.11	8736.60	203	223
4	1	3.72	Ca	0.13	415.95	229	250
5	1	6.10	Fe	0.15	1823.46	416	437
6		6.75	Fe	0.04	178.96	470	465
7	1	9.39	—	0.02	142.76	671	692
8	1	9.43	—	0.21	476.23	677	696

WID3/1290/TA-4
centroid adjustment : + 0.32

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		0.93	Mg	0.12	364.40	12	30
2	1	4.46	—	0.05	-0.25	31	51
3	1	1.64	—	0.13	1325.36	62	102
4	1	3.36	Ca	0.13	3567.66	203	223
5	1	3.71	Ca	0.09	430.46	229	249
6	1	6.09	Fe	0.13	1965.50	415	436
7	1	9.41	—	0.11	223.72	677	697

WID3/1300/AR-5
centroid adjustment : + 0.33

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	0.94	Mg	0.12	508.14	12	32
2	1	1.63	—	0.16	2007.10	62	102
3	1	3.36	Ca	0.13	3447.59	203	223
4	1	3.71	Ca	0.06	247.95	226	249
5	1	6.09	Fe	0.14	1913.75	415	436
6	1	6.75	Fe	0.14	357.54	467	467
7	1	9.40	—	0.13	419.53	675	696

WID3/2600/SP-6
centroid adjustment : + 0.31

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	0.94	Mg	0.11	644.30	11	32
2	1	1.63	—	0.16	3269.22	61	102
3	1	3.36	Ca	0.12	3205.61	203	223
4	1	6.09	Fe	0.15	2460.45	415	436
5	1	6.76	Fe	0.03	61.04	464	464
6	1	6.74	—	0.01	321.53	466	467
7	1	9.40	—	0.14	532.74	675	696

WID3/1300/SP-7
centroid adjustment : + 0.32

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	0.94	Mg	0.09	519.03	12	32
2	1	1.64	—	0.13	1169.11	62	102
3	1	3.36	Ca	0.13	3639.50	203	223
4	1	3.71	Ca	0.12	513.46	229	250
5	1	6.09	Fe	0.15	1027.00	415	436
6	1	6.77	Fe	0.01	106.63	469	469
7	1.	9.41	—	0.09	367.63	676	696

(continued)

WIR3/1100/TA-1
centroid adjustment : +0.0

```
NO. ECL      CENTROID          FWHM       AREA    LEFT RIGHT

 1   1          1.86   Mg      0.10      721.77    36    56
 2   1          2.15   —       0.15     1774.22   106   127
 3   1          3.70   Ca      0.13     4043.85   226   248
 4   1          4.02   Ca      0.11      717.33   253   273
 5   1          9.70   —       0.07      283.06   699   719
```

WIR3/2100/TA-2
centroid adjustment : +0.0

```
NO. ECL      CENTROID          FWHM       AREA    LEFT RIGHT

 1   1          1.85   Mg      0.11      822.55    35    56
 2   1          2.15   —       0.16     2163.45   106   127
 3   1          3.69   Ca      0.13     4328.21   227   248
 4   1          4.01   Ca      0.14      619.35   252   272
 5   1          9.69   —       0.08      303.10   696   716
```

WIR3/1100/SP-3
centroid adjustment : +0.0

```
NO. ECL      CENTROID          FWHM       AREA    LEFT RIGHT

 1   1          1.25   Mg      0.11     1767.45    36    57
 2   1          2.15   —       0.14     2362.38   107   127
 3   1          3.69   Ca      0.12     4556.73   227   248
 4              4.02   Ca      0.15      800.50   254   273
 5   1          9.70   —       0.02       91.53   697   718
```

WIR3/1100/SP-4
centroid adjustment : +0.0

```
NO. ECL      CENTROID          FWHM       AREA    LEFT RIGHT

 1              1.25   Mg      0.10     1048.58    36    56
 2   1          2.16   —       0.14     1970.99   107   127
 3   1          3.69   Ca      0.13     4037.22   228   246
 4              4.01   Ca      0.14      447.00   255   270
 5   1          9.69   —       0.09      305.48   698   718
 6   1          9.71   —       0.09      158.08   702   722
```

WIR3/2100/SP-5
centroid adjustment : +0.0

```
NO. ECL      CENTROID          FWHM       AREA    LEFT RIGHT

 1   1          1.25   Mg      0.10     1075.77    36    56
 2   1          2.15   —       0.13     2070.60   106   126
 3   1          3.69   Ca      0.13     4304.45   227   246
 4              4.01   Ca      0.02      518.97   253   273
 5   1          9.69   —       0.08      292.65   698   718
```

WIR3/2100/SP-6
centroid adjustment : +0.0

```
NO. ECL      CENTROID          FWHM       AREA    LEFT RIGHT

 1   1          1.26   Mg      0.13     1339.98    36    57
 2   1          2.15   —       0.15     2619.20   106   127
 3   1          3.69   Ca      0.12     4069.65   226   246
 4              4.02   Ca      0.12      639.96   254   273
 5   1          9.68   —       0.13      265.35   698   716
```

WIA3/250/TA-1
centroid adjustment . +0.03

```
NO. ECL      CENTROID          FWHM       AREA    LEFT RIGHT

 1   1          1.23   Mg      0.10      330.01     6    26
 2   1          2.13   —       0.16     2317.46    76    99
 3   1          3.67   Ca      0.13     2430.49   199   220
 4   1          3.96   Ca      0.10      145.74   227   247
 5   1          9.68   —       0.09      410.97   672   693
```

WIA3/1260/TA-2
centroid adjustment : +0.03

```
NO. ECL      CENTROID          FWHM       AREA    LEFT RIGHT

 1   1          1.22   Mg      0.11      381.01     7    26
 2   1          2.13   —       0.15     2352.25    76    99
 3   1          3.67   Ca      0.13     2492.33   200   220
 4   1          3.99   Ca      0.09      245.56   226   246
 5   1          9.67   —       0.16      464.22   671   692
```

WIA3/1260/AR-3
centroid adjustment . +0.02

```
NO. ECL      CENTROID          FWHM       AREA    LEFT RIGHT

 1   1          1.24   Mg      0.11      477.77     6    29
 2   1          2.14   —       0.14     2227.83    79    99
 3   1          3.67   Ca      0.13     2653.46   200   220
 4   1          9.69   —       0.15      481.36   673   693
```

(continued)

WIA3/250/SP-1
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.23	Mg	0.14	267.25	10	26
2	1	2.13	—	0.12	638.46	78	99
3	1	3.67	Ca	0.13	5104.25	200	220
4	1	4.00	Ca	0.11	532.47	226	247
5	1	6.37	Fe	0.03	213.01	411	438
6	1	9.69	—	0.10	186.63	673	693

WIA3/250/SP-2
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.71	Si	0.18	1034.04	45	66
2	1	2.13	—	0.14	2803.29	78	98
3	1	2.96	K	0.10	1060.89	144	164
4	1	3.67	Ca	0.13	476.20	199	220
5	1	9.66	—	0.09	457.36	672	692

WIA3/1260/SP-4
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.21	Mg	0.10	337.26	7	27
2		1.67	Si	0.06	150.51	40	59
3	1	2.12	—	0.16	4621.74	77	98
4	1	3.67	Ca	0.13	2883.20	199	220
5	1	9.66	—	0.17	739.23	670	691

WIA3/1260/SP-5
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.22	Mg	0.08	569.27	7	26
2	1	2.13	—	0.16	4350.50	78	99
3	1	3.67	Ca	0.12	2355.23	199	220
4	1	9.67	—	0.03	223.25	672	692

WIA3/2500/-SP-6
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.23	Mg	0.10	656.61	6	28
2	1	2.13	—	0.14	4374.47	78	99
3	1	3.66	Ca	0.12	2661.96	199	219
4	1	9.66	—	0.09	559.99	670	691
5	1	11.43	—	0.10	103.63	606	628

WIA3/2500/SP-7
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.23	Mg	0.12	731.78	7	26
2	1	2.13	—	0.16	4677.49	76	99
3	1	3.66	Ca	0.13	2419.75	199	219
4	1	9.66	—	0.13	539.09	671	691
5	1	13.27	—	0.09	110.97	954	974
6	1	13.23	—	0.06	38.16	956	976
7	1	13.47	—	0.13	72.00	970	990
8		13.80	—	0.05	41.61	1000	1014

WIA3/2500/SP-8
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.23	Mg	0.02	123.02	7	28
2	1	2.13	—	0.16	3040.48	76	99
3	1	3.67	Ca	0.12	1398.20	199	220
4	1	3.99	Ca	0.09	204.99	226	246
5	1	9.67	—	0.12	773.74	671	692
6	1	11.46	—	0.07	147.96	812	832

WIA3/2500/SP-9
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.22	Mg	0.06	356.27	7	26
2	1	2.12	—	0.15	5102.46	77	96
3	1	3.67	Ca	0.13	2247.95	199	220
4	1	9.66	—	0.15	660.00	671	691

(continued)

WK3/2400/AR-1
centroid adjustment : +0.01

```
NC. ECL     CENTRCID        FWHM        AREA   LEFT RIGHT

  1  1         1.47   Al    0.11      724.77    54    75
  2  1         1.74   Si    0.12     2567.96    74    95
  3  1         2.15   —     0.15     4636.47   106   127
  4  1         3.32   K     0.15      654.75   199   220
  5  1         3.70   Ca    0.09      129.66   230   250
  6  1         9.71   —     0.17     1003.46   699   720
  7  1        11.44   —     0.02       65.53   630   650
  8  1        11.40   —     0.10      234.02   632   652
```

WK3/2400/SP-2
centroid adjustment : +0.0

```
NC. ECL     CENTRCID        FWHM        AREA   LEFT RIGHT

  1            1.26   Mg    0.09      537.26    37    57
  2  1         1.51   Al    0.01      151.66    55    75
  3  1         2.16   —     0.15     3729.00   107   127
  4  1         3.69   Ca    0.13     9479.99   227   246
  5  1         4.02   Ca    0.11     1366.22   254   274
  6  1         9.70   —     0.11      666.10   699   719
```

WK3/2400/SP-3
centroid adjustment : +0.01

```
NC. ECL     CENTRCID        FWHM        AREA   LEFT RIGHT

  1            1.25   Mg    0.06      298.13    38    54
  2            1.46   Al    0.09      217.69    55    73
  3  1         1.74   Si    0.13     1261.60    75    95
  4  1         2.15   —     0.17     3149.33   107   127
  5            3.32   K     0.10      310.46   199   216
  6  1         3.69   Ca    0.13     1363.21   227   246
  7  1         9.70   —     0.13      450.33   699   719
```

WK3/1200/SP-4
centroid adjustment : +0.01

```
NC. ECL     CENTRGID        FWHM        AREA   LEFT RIGHT

  1            1.25   Mg    0.11      592.50    37    56
  2  1         2.15   —     0.14     4200.25   106   127
  3  1         3.70   Ca    0.15     2504.59   228   246
  4  1         9.69   —     0.14      689.21   696   716
  5           11.37   —     0.08       79.75   636   645
```

WK3/1200/SP-5
centroid adjustment : +0.0

```
NC. ECL     CENTRCID        FWHM        AREA   LFFT RIGHT

  1            1.49   Al    0.06      179.23    54    75
  2  1         3.68   Ca    0.09      134.75   226   246
  3  1         3.66   Ca    0.08       32.74   229   249
  4  1         6.40   Fe    0.09      571.23   440   461
  5  1         9.69   —     0.14      694.45   696   719
```

W07/2390/TA-1
centroid adjustment : +0.0

```
NC. ECL     CENTROID        FWHM        APEA   LEFT RIGHT

  1            1.49   Al    0.11      342.86    59    71
  2  1         1.74   Si    0.15      749.49    74    95
  3  1         2.16   —     0.16     2408.98   107   127
  4  1         3.69   Ca    0.14     2758.74   227   246
  5  1         4.01   Ca    0.09      362.63   253   273
  6  1         5.89   Mn    0.15      773.06   400   420
  7  1         6.39   Fe    0.16     1226.39   439   459
  8  1         9.67   —     0.14      226.53   696   717
```

W07/2390/SP-2
centroid adjustment : +0.01

```
NC. ECL     CENTROID        FWHM        AREA   LEFT RIGHT

  1            1.49   Al    0.10      421.64    54    74
  2  1         1.48   Al    0.10      306.17    57    77
  3  1         1.74   Si    0.11     1106.72    74    95
  4  1         2.15   —     0.15     2600.73   106   127
  5  1         3.69   Ca    0.13     2526.49   226   248
  6            4.02   Ca    0.14      352.25   256   272
  7  1         5.90   Mn    0.15      697.47   401   421
  8  1         6.40   Fe    0.13     1142.35   440   460
  9  1         9.68   —     0.08      439.00   697   717
```

W07/2390/SP-5
centroid adjustment : +0.01

```
NO. ECL     CENTROID        FWHM        AREA   LFFT RIGHT

  1  1         2.15   —     0.15     3651.96   106   127
  2  1         3.69   Ca    0.13     3456.97   226   246
  3            4.02   Ca    0.15      542.07   255   273
  4  1         5.88   Mn    0.05      344.55   399   420
  5  1         6.39   Fe    0.12      553.01   439   460
  6  1         9.68   —     0.13      533.45   697   718
  7  1        11.47   —     0.01      114.21   837   856
```

(continued)

W07/2390/SP-3
centroid adjustment : +0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.26	Mg	0.06	321.50	38	54
2	1	1.46	Al	0.10	975.55	54	75
3		1.74	Si	0.08	344.97	77	92
4	1	2.15	—	0.16	3464.72	106	127
5	1	3.68	Ca	0.14	1663.88	227	247
6	1	5.69	Mn	0.12	771.4	400	420
7	1	6.40	Fe	0.14	1120.85	440	460
6	1	9.67	—	0.02	355.35	697	717

W07/2390/SP-4
centroid adjustment : +0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.17	Mg	0.03	12.54	54	75
2		1.70	Si	0.11	413.03	78	91
3	1	2.15	—	0.15	3755.73	106	127
4	1	3.69	Ca	0.14	1965.6	227	247
5	1	5.69	Mn	0.13	856.98	400	421
6	1	6.40	Fe	0.16	1351.84	440	460
7	1	9.68	—	0.07	423.73	697	717
8	1	11.37	—	0.02	-21.85	831	851
9	1	12.45	—	0.06	25.42	917	937

W6D7/1930/TA-1
centroid adjustment : -0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.17	—	0.15	1662.50	108	129
2	1	3.72	Ca	0.11	1099.74	229	250
3	1	5.92	Mn	0.14	372.54	402	422
4	1	6.43	Fe	0.15	1323.96	442	462
5	1	7.06	Fe	0.15	291.03	491	511
6		7.11	Fe	0.02	28.50	501	510
7	1	9.67	—	0.14	270.39	696	716

W6D7/1930/SP-2
centroid adjustment : -0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.17	—	0.15	2512.36	106	126
2	1	3.73	Ca	0.03	78.65	231	251
3	1	5.91	Mn	0.07	536.39	401	421
4	1	6.42	Fe	0.16	1712.96	441	462
5	1	7.07	Fe	0.08	231.45	492	513

W6D7/1930/AR-3
centroid adjustment : -0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.27	Mg	0.04	176.27	36	58
2	1	2.17	—	0.13	1832.72	106	126
3	1	3.70	Ca	0.09	654.54	226	249
4	1	3.70	Ca	0.01	131.60	234	254
5	1	5.92	Mn	0.13	507.65	402	422
6	1	6.42	Fe	0.16	1519.24	441	462
7		9.66	—	0.06	96.00	699	712

W6D7/2040/SP-4
centroid adjustment : -0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.50	Al	0.15	266.00	59	75
2	1	2.17	—	0.16	1543.72	106	129
3	1	3.71	Ca	0.12	2250.21	229	249
4	1	4.06	Ca	0.02	245.84	259	279
5	1	6.42	Fe	0.15	772.50	441	462
6	1	9.70	—	0.02	184.99	699	719

W6D7/2040/SP-5
centroid adjustment : -0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.17	—	0.16	2264.9	106	129
2	1	3.71	Ca	0.13	1583.33	229	249
3	1	6.42	Fe	0.11	105.99	442	463

W6D7/2040/SP-6
centroid adjustment : -0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.17	—	0.16	2336.73	108	129
2	1	3.72	Ca	0.14	2404.74	229	250
3	1	6.39	Fe	0.03	109.01	436	459

W6D7/2040/AR-7
centroid adjustment : -0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.16	—	0.15	1727.95	106	129
2	1	3.71	Ca	0.12	1605.66	229	249
3	1	6.42	Fe	0.16	654.74	441	462
4	1	7.08	Fe	0.09	110.46	493	513

(continued)

WID7/280/TA-1
Centroid adjustment : + 0.31

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.15	Al	0.08	83.50	28	49
2	1	1.92	—	0.02	-4.85	31	51
3	1	1.64	—	0.13	965.08	82	102
4	1	3.36	Ca	0.13	1617.45	203	224
5	1	3.70	Ca	0.10	280.56	227	247
6	1	3.72	Ca	0,09	211.13	230	250
7	1	5.56	Mn	0.11	299.91	376	396
8	1	6.09	Fe	0.14	3982.49	415	436
9	1	6.75	Fe	0.06	444.96	467	488
10	1	9.40	—	0.11	281.35	675	695

WID7/1400/TA-2
centroid adjustment : + 0.33

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.17	Al	0.06	141.90	30	50
2	1	1.63	—	0.07	335.21	82	102
3	1	3.37	Ca	0.05	261.42	202	222
4	1	5.57	Mn	0.12	274.66	375	395
5		5.61	Mn	0.06	129.61	382	394
6	1	6.09	Fe	0.15	3920.70	415	436
7	1	6.73	Fe	0.17	593.99	466	487

WID7/2800/SP-3
Centroid adjustment : + 0.32

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.19	Al	0.05	42.00	34	47
2	1	1.64	—	0.13	579.63	82	102
3		3.38	Ca	0.09	810.75	204	222
4	1	6.09	Fe	0.14	2816.24	415	436
5	1	6.75	Fe	0.12	247.97	467	488
6	1	9.39	—	0.07	229.70	674	695

WID7/2800/SP-4
centroid adjustment : + 0.30

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.83	—	0.03	351.46	81	101
2	1	3.36	Ca	0.14	254.77	203	224
3	1	6.09	Fe	0.13	3631.34	416	436
4	1	6.73	Fe	0.10	431.54	465	486
5	1	9.36	—	0.14	258.41	671	691
6	1	9.41	—	0.12	243.97	676	697

WID7/1400/SP-5
Centroid adjustment : + 0.30

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	0.93	Mg	0.14	402.50	10	31
2	1	1.84	—	0.15	1756.60	82	102
3	1	3.38	Ca	0.13	920.75	203	223
4		3.67	Ca	0.09	146.99	230	242
5	1	5.59	Mn	0.15	626.21	376	397
6	1	6.09	Fe	0.16	4952.20	415	436
7	1	6.74	Fe	0.13	487.36	467	487
8	1	9.37	—	0.09	164.26	671	691
9	1	9.41	—	0.04	301.22	676	696

WID7/1400/AR-6
Centroid adjustment : + 0.32

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.16	Al	0.02	122.13	30	50
2	1	1.42	Si	0.12	234.26	50	70
3	1	1.64	—	0.14	570.73	82	103
4	1	3.37	Ca	0.12	1071.30	202	223
5	1	3.72	Ca	0.05	22.23	227	247
6	1	5.61	Mn	0.04	92.09	376	396
7	1	6.09	Fe	0.15	2814.46	415	436
8	1	6.74	Fe	0.11	346.46	467	487
9	1	9.39	—	0.14	266.74	675	695

WIR7/1300/TA-1
centroid adjustment : +0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.09	220.29	54	76
2	1	1.73	Si	0.15	709.29	74	94
3	1	2.14	—	0.16	1554.47	106	126
4	1	3.69	Ca	0.12	1990.24	227	246
5	1	5.69	Mn	0.14	872.97	400	421
6	1	6.40	Fe	0.16	1741.71	440	460
7	1	7.05	Fe	0.09	296.97	491	511
8	1	9.69	—	0.07	200.11	696	716

(continued)

WIR7/1300/SP-2
centroid adjustment : +0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.48	Al	0.12	1077.79	54	74
2	1	1.74	Si	0.08	555.60	75	95
3	1	2.15	—	0.17	1905.98	106	127
4	1	3.69	Ca	0.15	8995.99	227	248
5		4.01	Ca	0.12	413.70	252	273
6	1	5.89	Mn	0.09	153.25	400	420
7	1	6.40	Fe	0.12	804.58	440	460
8	1	9.69	—	0.16	217.88	699	719

WIR7/2600/SP-3
centroid adjustment : +0.0

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.14	—	0.11	1629.97	106	126
2	1	3.69	Ca	0.13	1923.61	228	248
3	1	5.89	Mn	0.11	460.99	400	421
4	1	6.40	Fe	0.15	791.59	440	460
5	1	9.72	—	0.04	128.24	700	720

WIR7/2000/SP-4
centroid adjustment : +0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.73	Si	0.07	354.42	73	93
2	1	2.15	—	0.14	2954.21	106	127
3	1	3.70	Ca	0.14	1584.47	228	248
4	1	6.37	Fe	0.05	136.40	439	459
5	1	9.67	—	0.07	299.75	697	717

WIR7/650/SP-5
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.24	Mg	0.12	1123.54	35	55
2		1.68	Si	0.02	176.00	74	87
3	1	2.15	—	0.16	3733.49	106	127
4	1	3.69	Ca	0.12	1897.73	227	248
5	1	5.87	Mn	0.04	125.22	401	421
6	1	6.39	Fe	0.10	1087.13	439	459
7	1	9.67	—	0.13	533.30	696	717

WIR7/1300/SP-6
centroid adjustment : +0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.19	—	0.02	59.66	37	57
2	1	2.15	—	0.14	1965.49	106	127
3	1	3.68	Ca	0.10	464.63	227	247
4	1	5.89	Mn	0.12	731.73	400	420
5	1	6.39	Fe	0.15	2024.47	439	460
6	1	7.03	Fe	0.05	102.13	490	510
7	1	9.69	—	0.20	334.46	698	719

WIA7/600/TA-1
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.72	Si	0.12	426.45	46	67
2	1	2.13	—	0.15	1876.45	78	99
3	1	6.37	Fe	0.14	2036.25	412	433
4	1	7.01	Fe	0.10	407.54	462	482
5	1	9.67	—	0.07	456.22	671	692

WIA7/600/SP-2
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.71	Si	0.13	1477.50	45	65
2	1	2.12	—	0.15	4122.45	77	98
3	1	6.37	Fe	0.14	966.49	411	432
4	1	9.66	—	0.12	491.71	672	693
5	1	11.46	—	0.10	196.60	813	833

WIA7/2350/AR-4
centroid adjustment : +0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.47	Al	0.06	233.41	27	47
2		1.72	Si	0.15	574.46	46	67
3	1	2.13	—	0.16	3223.74	76	99
4	1	6.37	Fe	0.15	1991.48	412	432
5	1	7.00	Fe	0.06	159.92	440	460
6	1	7.03	Fe	0.06	241.73	464	484
7	1	9.67	—	0.05	366.74	671	692
8	1	11.51	—	0.06	24.53	810	830

(continued)

WIA7/2360/SP-3
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.05	192.26	26	46
2	1	2.13	—	0.14	2011.83	78	98
3	1	6.37	Fe	0.14	2225.47	411	432
4	1	7.03	Fe	0.13	290.47	463	483
5	1	9.67	—	0.10	409.45	671	692

WIA7/2360/SP-5
centroid adjustment ; +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.11	948.14	26	46
2	1	1.71	Si	0.10	1476.46	46	66
3	1	2.13	—	0.16	2766.46	78	99
4	1	3.67	Ca	0.11	237.99	198	219
5	1	6.37	Fe	0.12	583.09	412	432
6	1	9.67	—	0.05	243.23	670	691

WIA7/2360/SP-6
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.45	Al	0.10	1760.00	25	45
2	1	1.71	Si	0.12	4667.45	45	66
3	1	2.12	—	0.15	3344.73	77	98
4	1	3.66	Ca	0.09	1099.08	199	219
5	1	6.36	Fe	0.13	307.96	412	432
6	1	9.66	—	0.11	376.09	671	691

WIA7/2360/SP-7
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.66	Si	0.14	190.61	45	65
2	1	2.12	—	0.15	6212.72	77	96
3	1	6.36	Fe	0.12	1862.97	411	431
4	1	9.66	—	0.16	791.96	670	691
5		11.40	—	0.13	266.40	610	624
6	1	11.43	—	0.16	446.84	810	830

WIA7/580/SP-8
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.12	—	0.13	3524.50	77	98
2	1	6.36	Fe	0.14	4430.45	411	432
3	1	7.01	Fe	0.02	719.21	462	482
4	1	9.66	—	0.16	680.99	670	691
5	1	11.40	—	0.06	271.55	637	[illegible]

WIA7/1160/SP-9
centroid adjustment +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.67	Si	0.08	153.66	47	59
2	1	1.71	Si	0.06	460.66	47	67
3	1	2.12	—	0.14	4692.74	77	98
4	1	6.36	Fe	0.14	1744.75	411	431
5	1	7.01	Fe	0.15	304.34	462	482
6	1	9.66	—	0.14	736.50	671	691
7	1	11.42	—	0.11	260.77	609	630

WIA7/1160/SP-10
centroid adjustment +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.41	Al	0.05	91.14	25	45
2	1	1.72	Si	0.14	626.23	46	66
3	1	2.13	—	0.15	2401.33	76	96
4	1	6.37	Fe	0.14	2672.97	412	433
5	1	7.03	Te	0.13	263.22	464	485
6	1	9.67	—	0.13	254.40	671	692

WIC7/44/TA-1
centroid adjustment : +0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.11	434.52	54	75
2	1	2.15	—	0.16	1962.25	106	127
3	1	3.66	Ca	0.12	463.23	226	247
4	1	5.90	Mn	0.09	310.49	401	422
5	1	6.40	Fe	0.15	406.77	439	460
6	1	9.69	—	0.14	653.95	696	719
7	1	11.46	—	0.08	124.45	630	657

(continued)

WIC7/650/TA-2
centroid adjustment : +0.01

NC.	ECL	CENTHOID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Al	0.04	301.75	55	75
2	1	8.15	—	0.15	2147.75	106	127
3	1	3.70	Ca	0.14	365.75	227	248
4	1	5.66	Mn	0.11	304.30	399	420
5	1	6.41	Fe	0.08	520.46	440	461
6	1	9.69	—	0.10	666.23	698	719
7	1	11.46	—	0.19	532.59	637	657
8	1	11.49	—	0.12	252.10	840	660

WIC7/650/SP-3
centroid adjustment : +0.01

NO.	ECL	CENTHOID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Al	0.10	218.67	54	74
2	1	8.15	—	0.15	1493.34	107	127
3	1	3.70	Ca	0.05	351.22	226	249
4	1	5.69	Mn	0.03	242.25	400	420
5	1	6.41	Fe	0.11	567.34	441	461
6	1	9.66	—	0.15	1162.60	697	717
7		11.44	—	0.02	27.66	843	647
6	1	11.46	—	0.16	425.72	637	856

WIC7/1300/SP-4
centroid adjustment : +0.01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGFT
1	1	7.09	Fe	0.16	-1.73	53	74
8	1	1.72	Si	0.11	946.46	73	93
3	1	2.15	—	0.16	6072.72	106	127
4	1	6.46	Mn	0.02	41.55	439	460
5	1	9.66	—	0.13	646.30	697	716
6	1	11.39	—	0.03	233.03	831	852

WIC7/1300/SP-8
centroid adjustment : +0.0

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.15	—	0.14	3215.73	106	127
8	1	3.71	Ca	0.16	426.99	226	249
3	1	9.69	—	0.13	753.97	698	718
4	1	11.37	—	0.05	218.02	626	649
5	1	11.41	—	0.02	121.05	831	852

W08/2700/TA-1
centroid adjustment = +0 01

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.08	191.53	53	74
2	1	2.15	—	0.17	2770.96	106	127
3	1	3.69	Ca	0.16	2237.48	227	248
4		4.02	Ca	0.02	393.72	254	274
5	1	6.40	Fe	0.15	325.50	440	460
6	1	9.69	—	0.14	1151.71	698	718

W05/67/TA-2
centroid adjustment +0 0

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Al	0.12	245.04	56	76
2	1	2.16	—	0.14	2250.45	107	126
3	1	3.69	Ca	0.15	1326.20	227	248
4		4.02	Ca	0.06	175.04	254	272
5		4.04	Ca	0.06	169.63	259	271
6	1	6.41	Fe	0.06	407.98	440	461
7	1	9.66	—	0.14	677.39	697	717

W6D5/2600/TA-1
centroid adjustment : +0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Al	0.11	1935.48	55	76
2	1	2.14	—	0.08	165.53	106	126
3	1	3.68	Ca	0.04	36.53	228	249
4	1	9.67	—	0.08	332.54	696	717
5	1	11.45	—	0.01	80.38	836	856

W6D5/2700/TA-2
centroid adjustment : +0.0

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.10	1852.70	55	76
2	1	1.74	Si	0.00	-214.16	75	95
3	1	1.76	Si	0.07	193.39	77	97
4		2.16	—	0.13	316.46	107	128
5	1	3.68	Ca	0.08	57.77	226	247
6	1	9.70	—	0.11	335.24	699	719

(continued)

WDS/2600/SP-3
centroid adjustment : +0.0

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.11	2122.97	55	76
2	1	2.17	—	0.02	198.23	107	128
3	1	8.19	—	0.04	101.46	110	130
4	1	9.69	—	0.08	370.59	699	719

WDS/2600/SP-4
centroid adjustment : +0.0

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Al	0.12	2432.00	55	76
2	1	2.17	–	0.11	378.00	108	128
3	1	9.69	-	0.15	347.74	698	718

WDS/2700/SP-5
centroid adjustment : +0.0

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.11	2088.95	55	76
2	1	2.16	—	0.03	67.02	106	126
3	1	2.20	–	0.16	294.21	110	131
4		3.02	–	0.13	111.00	176	193
5		3.70	Ca	0.08	158.23	227	246
6	1	9.69	—	0.12	315.78	697	718

WDS/2700/SP-6
centroid adjustment : +0.0

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.11	2185.99	55	76
2	1	2.16	–	0.10	125.46	108	128
3	1	9.69	–	0.07	387.47	698	718
4	1	11.53	–	0.15	249.97	842	862

WDS/2700/SP-7
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.12	2520.72	55	76
2	1	9.67	—	0.14	584.26	696	717

WIDS/2320/TA-1
centroid adjustment : +0.32

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	0.99	Mg	0.03	-79.00	11	32
2.	1	1.15	Al	0.16	408.30	29	50
3	1	1.42	Si	0.13	1066.53	49	70
4	1	1.83	—	0.13	1874.66	82	102
5	1	3.38	Ca	0.13	2458.06	203	223
6	1	6.09	Fe	0.13	1534.74	415	436
7	1	6.75	Fe	0.04	195.71	467	487
6	1	9.39	—	0.05	114.54	674	695

WIDS/2320/SP-2
centroid adjustment : +0.33

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.16	Al	0.08	383.05	29	50
2	1	1.41	Si	0.18	793.70	48	69
3	1	1.63	—	0.15	4773.73	81	102
4	1	3.38	Ca	0.13	1077.00	203	223
5	1	6.09	Fe	0.15	2462.99	415	436
6	1	6.75	Fe	0.14	395.63	466	488
7	1	9.39	—	0.05	346.86	675	695

WIDS/1160/SP-3
centroid adjustment : +0.36

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.83	—	0.14	1016.54	61	102
2		2.00	S	0.05	207.00	95	111
3		2.30	Cl	0.09	225.68	120	136
4	1	2.67	–	0.12	2151.89	147	167
5		2.65	–	0.02	315.63	166	160
6	1	6.09	Fe	0.13	1153.59	416	436
7	1	9.35	–	0.03	172.26	671	691

WIDS/1160/SP-4
centroid adjustment +0.33

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.16	Al	0.13	430.01	29	50
2	1	3.39	Ca	0.13	567.72	204	224
3	1	6.09	Fe	0.15	3442.22	415	436
4	1	6.75	—	0.15	372.05	466	488
5	1	9.36	—	0.09	242.75	673	693

(continued)

WIDS/1160/SP-5
centroid adjustment : +0.31

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.14	Al	0.04	199.26	29	49
2	1	1.43	Si	0.13	1304.98	50	70
3	1	1.65	—	0.13	1103.22	82	103
4	1	2.64	—	0.02	116.13	147	167
5		2.97	K	0.03	21.74	177	191
6	1	3.36	Ca	0.14	2590.74	203	223
7	1	3.70	Ca	0.05	219.74	228	249
8	1	6.09	Fe	0.13	1749.72	416	436
9	1	6.75	Fe	0.11	268.46	467	486
10	1	9.37	—	0.09	171.26	672	693
11	1	9.41	—	0.04	261.73	676	697

WIDS/1160/SP-6
centroid adjustment : +0.32

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.20	Al	0.10	65.78	30	50
2		1.45	Si	0.12	47.14	47	65
3	1	1.41	Si	0.13	351.80	49	70
4	1	1.84	—	0.15	3212.00	82	103
5		2.32	Cl	0.15	220.63	119	139
6	1	3.36	Ca	0.11	690.34	203	223
7	1	3.74	Ca	0.02	-66.86	229	249
8	1	6.09	Fe	0.14	2411.70	415	436
9	1	6.74	Fe	0.14	233.73	467	487
10	1	9.39	—	0.18	716.00	674	695

WIDS/1160/SP-7
centroid adjustment : +0.32

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.14	Al	0.18	83.27	29	49
2	1	1.41	Si	0.14	595.03	49	70
3	1	1.84	—	0.15	2394.47	82	103
4	1	3.36	Ca	0.12	1274.96	203	224
5	1	3.70	Ca	0.01	140.39	229	249
6	1	5.59	Mn	0.06	160.23	375	396
7	1	6.10	Fe	.13	1713.49	416	436
8	1	6.75	Fe	0.13	842.70	467	488
9	1	9.39	—	0.16	469.03	675	695

WIDS/1150/SP-8
centroid adjustment : +0.32

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.16	Al	0.09	163.01	32	47
2	1	1.64	—	0.14	2766.63	62	102
3	1	3.37	Ca	.14	445.97	202	222
4	1	6.09	Fe	0.12	2667.73	415	436
5	1	6.74	Fe	0.06	371.70	466	487
6	1	9.39	—	0.08	422.96	674	695

WIDS/1150/SP-9
centroid adjustment : +0.33

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.15	Al	0.01	252.79	26	49
2	1	1.63	—	0.15	3795.22	81	102
3		2.29	Cl	0.07	44.04	118	136
4	1	3.37	Ca	0.15	535.42	202	222
5	1	6.09	Fe	0.14	3092.20	415	436
6	1	6.75	Fe	0.13	333.96	468	469
7	1	9.39	—	0.17	676.99	674	695
8	1	10.90	—	0.01	-44.65	790	810

WIRS/1340/SP-1
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.12	403.45	54	75
2	1	9.67	—	0.16	523.04	697	717

WIRS/1340/AR-2
centroid adjustment : +0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.47	Al	0.10	295.40	54	74
2	1	2.14	—	0.15	932.99	105	126
3	1	3.66	Ca	0.13	1010.96	226	247
4	1	4.00	Ca	0.14	140.99	252	273
5	1	9.68	—	0.13	566.25	697	717
6	1	11.40	—	0.01	274.52	831	852

(continued)

WIRS/2680/AR-2
centroid adjustment : +0.0

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.75	Si	0.13	858.86	75	95
2	1	2.14	—	0.14	914.90	106	126
3	1	3.69	Ca	0.15	2333.45	227	248
4	1	9.72	—	0.15	299.56	701	721

WIRS/1340/SP-4
centroid adjustment : +0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.47	Al	0.05	202.51	53	73
2	1	2.15	—	0.14	1125.42	107	127
3	1	6.61	Zn	0.14	1138.08	614	634
4	1	9.63	—	0.18	466.04	692	712
5	1	9.69	—	0.13	340.22	697	718

WIRS/1340/SP-5
centroid adjustment : +0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.47	Al	0.02	150.38	53	73
2	1	2.14	—	0.06	195.79	108	128
3	1	2.30	S	0.03	242.73	119	140
4	1	3.68	Ca	0.06	99.61	229	249
5	1	6.62	Zn	0.15	1502.75	614	634
6	1	9.66	—	0.07	290.24	696	717
7	1	11.43	—	0.16	293.00	834	855

WIRS/2680/SP-6
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.31	S	0.09	921.36	120	140
2	1	6.63	Zn	0.13	1133.85	615	635
3	1	9.62	—	0.05	216.46	693	714

WIAS/580/TA-1
Centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.45	Al	0.09	167.01	27	41
2	1	1.71	Si	0.12	4327.45	45	66
3	1	2.18	—	0.15	4497.36	76	96
4		6.35	Fe	0.02	50.63	413	429
5	1	9.67	—	0.13	491.97	671	692
6	1	13.54	—	-0.00	-3.56	956	976

WIAS/580/AR-2
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.42	Al	0.05	164.52	25	46
2	1	1.71	Si	0.11	1986.30	45	66
3	1	2.12	—	0.15	4518.73	77	98
4	1	6.36	Fe	0.12	263.66	410	430
5	1	6.38	Fe	0.11	302.74	413	434
6	1	9.67	—	0.13	664.73	671	692
7	1	11.42	—	0.10	193.63	806	826
8	1	11.44	—	0.16	465.14	811	831

WIAS/1100/SP-3
Centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.44	Al	0.10	543.02	27	41
2	1	1.71	Si	0.12	4136.20	45	66
3	1	2.12	—	0.15	5444.74	77	98
4	1	3.66	Ca	0.11	774.46	196	219
5	1	9.67	—	0.15	422.47	671	692
6	1	11.45	—	0.11	326.88	812	832

WIAS/1100/SP-4
Centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.48	Al	0.06	-179.70	25	46
2	1	1.71	Si	0.12	3651.72	45	66
3	1	2.12	—	0.14	3164.13	78	96
4	1	3.66	Ca	0.07	899.47	196	219
5	1	9.68	—	0.13	599.97	672	692
6	1	11.36	—	0.03	113.03	805	825

(continued)

WICS/232/TA-1.
centroid adjustment ? + 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.73	Si	0.15	988.48	74	94
2.	1	2.15	—	0.13	1873.70	106	127
3	1	3.69	Ca	0.14	1442.22	227	247
4	1	9.70	—	0.11	223.99	698	719

WICS/232/AR-2
centroid adjustment : + 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.47	Al	0.04	201.88	55	75
2	1	1.73	Si	0.10	665.89	74	94
3	1	2.15	—	0.16	2636.95	106	127
4	1	3.69	Ca	0.12	1634.49	228	248
5	1	9.67	—	0.08	537.66	697	717
6	1	11.42	—	0.02	298.00	834	854

WICS/1160/AR-3
centroid adjustment : +0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.48	Al	0.08	128.41	53	73
2	1	1.72	Si	0.09	932.70	73	94
3	1	2.14	—	0.14	3307.34	106	126
4	1	3.68	Ca	0.13	2388.83	227	247
5	1	9.69	—	0.16	668.50	698	718

WICS/232/SP-4
centroid adjustment : + 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.48	Al	0.12	4194.74	54	75
2	1	2.15	—	0.18	3862.74	106	127
3	1	3.69	Ca	0.10	183.77	226	246
4	1	9.67	—	0.15	729.70	696	717
5	1	11.33	—	0.06	-34.96	630	650

WICS/232/SP-5
centroid adjustment : + 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Al	0.05	98.89	53	73
2	1	2.15	—	0.13	1323.66	107	127
3	1	4.50	—	0.15	386.53	291	312
4	1	6.39	Fe	0.14	4262.71	439	460
5	1	7.05	Fe	0.15	496.45	491	512
6	1	9.66	—	0.13	389.15	696	716

WICS/232/SP-6
centroid adjustment : + 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.45	Al	0.06	16.66	56	76
2	1	1.73	Si	0.11	256.65	74	94
3	1	2.15	—	0.12	316.13	107	127
4	1	3.70	Ca	0.14	2192.96	226	248
5	1	9.69	—	0.17	589.23	697	716

WICS/232/SP-7
centroid adjustment : + 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.07	463.53	54	74
2		1.74	Si	0.14	449.72	76	93
3	1	2.15	—	0.14	3171.75	106	127
4	1	6.40	Fe	0.15	1479.50	440	460
5	1	9.69	—	0.10	366.63	698	718

WICS/2320/SP-8
centroid adjustment : + 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.73	Si	0.12	1010.23	73	94
2	1	2.14	—	0.15	4137.47	106	126
3	1	3.66	Ca	0.14	1773.25	227	247
4	1	9.67	—	0.13	429.09	697	717
5		11.42	—	0.14	136.25	835	655

(continued)

WICS/2330/SP-9
Centroid adjustment : +0.01

```
NO. ECL      CENTROID          FWHM         AREA    LEFT RIGHT

 1             1.26   Mg      0.09        225.13     41    53
 2   1         1.44   Al      0.06         64.40     54    74
 3   1         1.73   Si      0.11       1456.13     74    94
 4   1         2.15   —       0.14       2573.72    106   127
 5   1         3.69   Ca      0.13       2295.72    227   248
 6   1         9.66   —       0.16        352.3    695   716
 7   1         9.71   —       0.14        219.08    702   722
 6   1        13.30   —       0.07         59.54    981  1001
```

WICS/2330/SP-10
Centroid adjustment : +0.02

```
NO. ECL      CENTROID          FWHM         AREA    LEFT RIGHT

 1             1.49   Al      0.08        303.27     56    72
 2             1.73   Si      0.13       1915.01     73    94
 3   1         2.14   —       0.14       4326.97    106   126
 4   1         3.69   Ca      0.13       1603.20    227   248
 5   1         9.68   —       0.10        656.45    697   716
```

APPENDIX E :

INTERPRETATION OF XRD ANALYSES OF CORE SAMPLES FROM HIGHWAY 401 TEST SECTIONS

E.1 ANALYSIS PROCEDURE

Unlike the aggregates which were discussed in Appendix D, the aggregates discussed in this appendix were obtained from the cores taken from the Highway 401 Test Sections during the Spring of 1979. Information on these test sections is given in Appendix B.

Basically, there are three types of aggregates involved:

a. traprock;

b. Stelco steel slag; and

c. blast furnace slag

Overall results of the SEM study of these test section aggregates are given in Chapter 4. The procedure adopted were similar to those given in Appendix D.

E.2 SUMMARY TABLES

The results of the XRD analysis are given in Tables E-1 to E-3. The explanation of the Table entry number is as follows:

Example : C3S5 - TR/2000/TA-1

C3 : core number (in this case core number 3)

S5 : stub number (in this case, this is stub number 5) (which contains a stone from core number 3)

TR : Type of aggregate

- TR : traprock
- SS : Stelco steel slag
- BFS : blast furnace slag

2000 : magnification (in this case X2000)

TA/SP/AR : see explanation in Appendix D

1 : entry number

E.3 CHEMICAL ELEMENT STATISTICS OF XRD ANALYSES

Final graphs, which summarize the findings obtained in Table E-1 to E-3 are given in Figures E-1 to E-3.

Table E-1. XRD Analyses for Traprock (Highway 401 Test Sections)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS														
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others
TEST SECTION 1		CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED											
CORE # 1, stub # 1																
contaminents	TR/990/SP-1													✓		Mn
	TR/5000/SP-2						✓		✓					✓	✓	Mn
	TR/2430/SP-3								✓					✓	✓	
	TR/2430/SP-4						✓		✓					✓	✓	
	TR/2430/SP-5						✓		✓					✓	✓	
CORE # 1, stub # 2																
contaminants	TR/480/SP-1							✓	✓					✓	✓	
	TR/480/SP-2													✓	✓	
	TR/480/SP-3													✓		
	TR/480/SP-4													✓	✓	
	TR/480/SP-5								✓					✓		
	TR/480/SP-6								✓					✓		
	TR(480/SP-7								✓					✓		
	TR/490/SP-8													✓		
	TR/490/SP-9								✓					✓		
	TR/490/SP-10								✓					✓		
CORE # 2, stub # 3																
contaminants	TR/1000/SP-1							✓	✓					✓		
	TR/1000/SP-2							✓	✓					✓	✓	
	TR/970/SP-3								✓					✓		
	TR/970/SP-4								✓					✓		
	TR/970/SP-5							✓	✓					✓		
CORE # 2, stub # 4																
surface characteristic	TR/200/TA-1								✓					✓	✓	
	TR/500/TA-2								✓					✓	✓	
	TR/500/TA-3								✓					✓	✓	
contaminents	TR/480/SP-4								✓					✓	✓	
	TR/480/SP-5													✓		
	TR/480/SP-6							✓	✓				✓	✓		
	TR/480/SP-7													✓		

(continued)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS														
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others
	TR/480/SP-8	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED			✓	✓					✓		
	TR/480/SP-9							✓	✓					✓	✓	
CORE # 3, Stub # 5																
surface characteristic	TR/2000/TA-1							✓	✓						✓	
	TR/1000/TA-2							✓	✓					✓	✓	
	TR/1000/TA-3							✓	✓					✓		
contaminants	TR/1080/SP-4								✓					✓	✓	
	TR/1080/SP-5							✓	✓					✓		
	TR/1080/SP-6							✓	✓					✓	✓	
	TR/1080/SP-7							✓	✓					✓		
	TR/550/SP-8							✓	✓							
	TR/550/SP-9							✓	✓							
	TR/550/SP-10								✓					✓	✓	
CORE # 3, Stub # 6																
surface characteristic	TR/1200/TA-1								✓						✓	
	TR/1200/TA-2								✓					✓	✓	
	TR/2400/TA-3								✓					✓	✓	
contaminants	TR/560/SP-4								✓					✓	✓	
	TR/560/SP-5													✓		
	TR/660/SP-6								✓					✓	✓	
	TR/660/SP-7							✓	✓							
	TR/1200/SP-8							✓	✓						✓	
	TR/1200/SP-9														✓	
TEST SECTION 3:																
CORE # 4, Stub # 7																
surface characteristic	TR/500/TA-1							✓	✓					✓	✓	
	TR/1000/TA-2							✓	✓					✓	✓	
	TR/1100/TA-3							✓	✓				✓	✓	✓	
contaminants	TR/1190/SP-4							✓	✓					✓		
	TR/1140/SP-5							✓	✓					✓	✓	
	TR/1190/SP-6							✓	✓					✓	✓	

(continued)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS														
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others	
	TR/1190/SP-7	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED			✓	✓					✓	✓		
	TR/1140/SP-8							✓	✓					✓	✓		
	TR/1190/SP-9							✓	✓					✓	✓		
	TR/1140/SP-10							✓	✓					✓	✓		
	TR/1190/SP-11							✓	✓					✓	✓		
CORE #4, Stub# 8																	
Surface characterutic	TR/550/TA-1														✓	Cr	
	TR/1100/TA-2														✓	Mn	
	TR/1100/TA-3							✓							✓	Cr	
	TR/1100/TA-4														✓	Cr	
contaminants	TR/830/SP-5						✓							✓	✓		
	TR/830/SP-6							✓						✓	✓		
	TR/830/SP-7							✓	✓					✓	✓		
	TR/830/SP-8													✓	✓	Mn	
CORE #5, stub # 9																	
Surface characteristic	TR/1050/TA-1						✓		✓					✓	✓		
	TR/2200/TA-2							✓	✓					✓	✓		
contaminants	TR/420/SP-3							✓	✓					✓			
	TR/420/SP-4								✓								
	TR/420/SP-5							✓	✓					✓			
	TR/420/SP-6								✓								
	TR/420/SP-7							✓	✓					✓	✓		
	TR/420/SP-8							✓	✓					✓	✓		
CORE # 5, Stub# 10																	
surface characteristic	TR/1200/TA-1							✓	✓					✓	✓		
	TR/1200/TA-2								✓					✓	✓		
	TR/1200/TA-3							✓	✓					✓	✓		
contaminants	TR/500/SP-4						✓		✓					✓			
	TR/500/SP-5							✓	✓					✓	✓		
	TR/500/SP-6							✓	✓					✓	✓		
	TR/2600/SP-7						✓	✓	✓					✓	✓		
	TR/2600/SP-8								✓					✓	✓		

(continued)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS														
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others
CORE # 6, stub # 11		CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED											
Surface characteristic	TR/2200/TA-1							✓	✓					✓	✓	
	TR/5500/TA-2						✓	✓	✓					✓	✓	
Contaminants	TR/2600/SP-3						✓	✓	✓					✓	✓	
	TR/2600/SP-4								✓					✓	✓	
	TR/2600/SP-5						✓		✓					✓	✓	
	TR/2600/SP-6						✓		✓					✓	✓	
CORE # 6, stub # 12																
Surface characteristic	TR/1000/TA-1							✓	✓							
	TR/1000/TA-2							✓	✓					✓		
Contaminants	TR/2000/SP-3							✓	✓					✓	✓	
	TR/2000/SP-4						✓	✓	✓					✓	✓	
	TR/2000/SP-5						✓	✓						✓		
	TR/2000/SP-6							✓	✓					✓	✓	
TEST SECTION 13:																
CORE # 14, stub # 25																
contaminants	TR/520/SP-1						✓		✓					✓	✓	
	TR/520/SP-2								✓					✓	✓	
	TR/520/SP-3								✓					✓	✓	
	TR/1025/SP-4						✓		✓					✓	✓	
	TR/1025/SP-5								✓					✓	✓	
	TR/5100/SP-6								✓					✓	✓	
CORE # 14, stub # 26																
Contaminants	TR/970/SP-1								✓						✓	
	TR/970/SP-2								✓					✓	✓	
	TR/970/SP-3							✓						✓	✓	
	TR/970/SP-4						✓		✓					✓	✓	
	TR/970/AR-5							✓	✓					✓	✓	
	TR/970/SP-6						✓		✓					✓	✓	
	TR/970/SP-7						✓	✓	✓					✓	✓	
CORE # 15, stub # 27																

(continued)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS														
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others
contaminants	TR/570/SP-1	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED				✓					✓	✓	
	TR/570/SP-2							✓	✓						✓	
	TR/1140/SP-3							✓							✓	
	TR/1140/SP-4							✓							✓	
	TR/2280/SP-5							✓						✓	✓	
	TR/2280/SP-6							✓							✓	
	TR/2280/SP-7							✓							✓	
CORE # 15, stub # 28																
contaminants	TR/2200/SP-1													✓	✓	
	TR/2200/SP-2								✓					✓	✓	
	TR/2200/SP-3								✓					✓	✓	
	TR/2200/SP-4								✓					✓	✓	
	TR/2200/SP-5								✓						✓	

Table E-2. XRD Analyses for Stelco Steel Slag (Highway 401 Test Sections)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS															
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others	
TEST SECTION 7:		CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED												
CORE # 7, stub # 13																	
surface characteristic	SS/1000/TA-1													✓			
	SS/1100/TA-2													✓			
	SS/2100/TA-3								✓					✓			
contaminants	SS/475/SP-4								✓					✓	✓		
	SS/475/SP-5													✓			
	SS/475/SP-6							✓	✓					✓		Zn	
	SS/475/SP-7								✓					✓			
	SS/475/SP-8							✓	✓					✓	✓		
CORE # 7, stub # 14																	
surface characteristic	SS/950/TA-1													✓			
	SS/950/TA-2							✓						✓			
	SS/1050/TA-3													✓			
contaminants	SS/1760/SP-4							✓	✓					✓			
	SS/1760/SP-5							✓	✓				✓	✓			
	SS/1760/SP-6							✓						✓			
	SS/1760/SP-7								✓					✓	✓	Mn	
	SS/1760/SP-8													✓	✓		
	SS/880/SP-9							✓						✓	✓		
	SS/440/SP-10													✓			
CORE # 8, stub # 15																	
surface characteristic	SS/550/TA-1													✓			
	SS/1050/TA-2													✓			
	SS/1100/TA-3													✓			
contaminants	SS/450/SP-4											✓		✓			
	SS/450/SP-5													✓			
CORE # 8, stub # 16																	
surface characteristic	SS/525/TA-1							✓	✓					✓	✓		
	SS/1150/TA-2							✓	✓					✓	✓		
	SS/2100/TA-3								✓					✓	✓		
contaminants	SS/460/SP-4								✓					✓	✓		

(continued)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS															
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others	
	SS/460/SP-5	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED				✓					✓	✓		
	SS/460/SP-6							✓	✓					✓	✓		
	SS/460/SP-7													✓	✓		
	SS/460/SP-8								✓					✓	✓		
	SS/1850/SP-9						✓	✓	✓					✓	✓		
CORE #9, Stub #17																	
contaminants	SS/1140/AR-1								✓					✓	✓		
	SS/1140/AR-2							✓						✓	✓		
	SS/1140/SP-3							✓						✓	✓	Cr	
	SS/1140/SP-4							✓						✓	✓	Cr	
CORE #9, stub# 18																	
surface characteristic	SS/620/TA-1								✓					✓	✓		
	SS/625/TA-2														✓	Cr	
	SS/625/TA-3								✓					✓			
	SS/1100/SP-4							✓						✓	✓		
contaminants	SS/1100/SP-5								✓					✓	✓		

Table E-3. XRD Analyses for Blast Furnace Slag (Highway 401 Test Sections)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS														
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others
TEST SECTION 9:		CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED											
CORE #10, stub #19																
contaminants	BFS/600/SP-1								✓						✓	
	BFS/1200/SP-2														✓	
	BFS/1200/SP-3							✓							✓	
	BFS/1200/SP-4							✓							✓	
	BFS/1200/SP-5							✓							✓	
	BFS/2400/SP-6								✓					✓	✓	
	BFS/2400/SP-7								✓						✓	
	BFS/2400/SP-8							✓							✓	
	BFS/2400/SP-9								✓					✓	✓	
	BFS/2400/SP-10								✓					✓	✓	
CORE #10, stub #20																
surface characteristic	BFS/1100/TA-1							✓						✓		
contaminants	BFS/1100/SP-2							✓	✓					✓		
	BFS/1100/SP-3							✓						✓	✓	
	BFS/1100/SP-4							✓						✓		
	BFS/1100/SP-5							✓						✓	✓	
CORE #11, stub #21																
surface characteristic	BFS/1300/TA-1								✓					✓		
	BFS/1300/AR-2							✓	✓					✓	✓	
	BFS/1300/AR-3							✓	✓					✓		
contaminants	BFS/690/SP-4							✓	✓					✓		
	BFS/690/SP-5							✓	✓					✓		
	BFS/1300/SP-6								✓			✓	✓	✓		
	BFS/1300/SP-7								✓					✓	✓	Mn
	BFS/1400/SP-8							✓	✓					✓		
	BFS/1400/SP-9							✓						✓		
	BFS/1400/SP-10								✓					✓		
	BFS/1400/SP-11							✓	✓					✓		
	BFS/2000/SP-12								✓					✓		
CORE #11, stub #22																

(continued)

DESCRIPTIONS	ENTRY NUMBER	LIST OF THE MOST POSSIBLE ELEMENTS														
		H	C	N	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Others
Surface characteristic	BFS/250/AR-1	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED	CANNOT BE DETECTED				✓					✓		
	BFS/650/AR-2								✓					✓		
Contaminants	BFS/250/SP-3								✓							
	BFS/250/SP-4								✓							
	BFS/250/SP-5								✓							
	BFS/650/SP-6								✓			✓		✓		
	BFS/650/SP-7								✓					✓		
CORE #12, stub# 24																
Contaminants	BFS/460/SP-1							✓	✓					✓	✓	
	BFS/920/SP-2							✓						✓	✓	
	BFS/1830/SP-3							✓	✓					✓	✓	
	BFS/1830/SP-4							✓	✓					✓	✓	

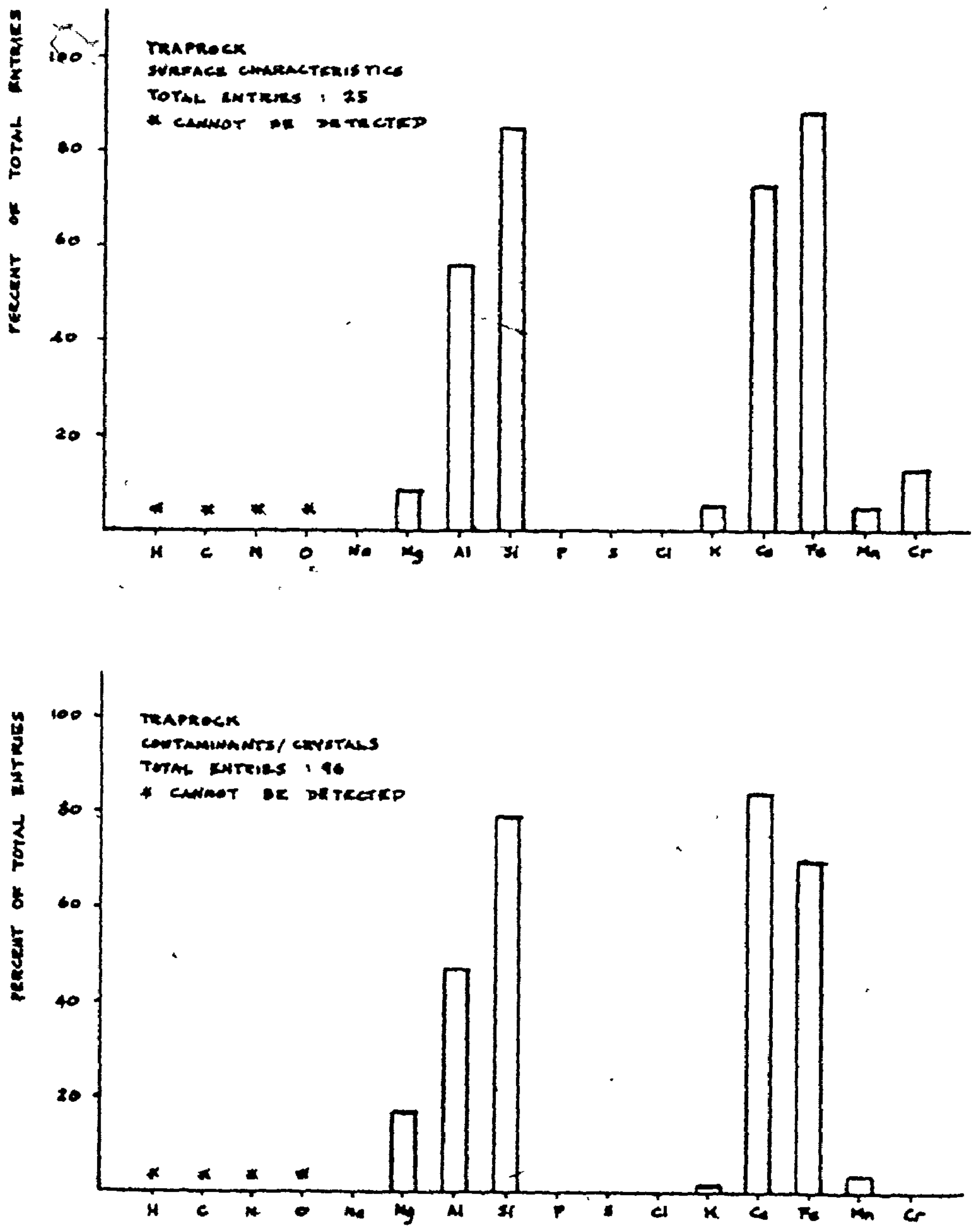


Figure E-1. Chemical Element Statistics for Traprock (Highway 401 Test Sections)

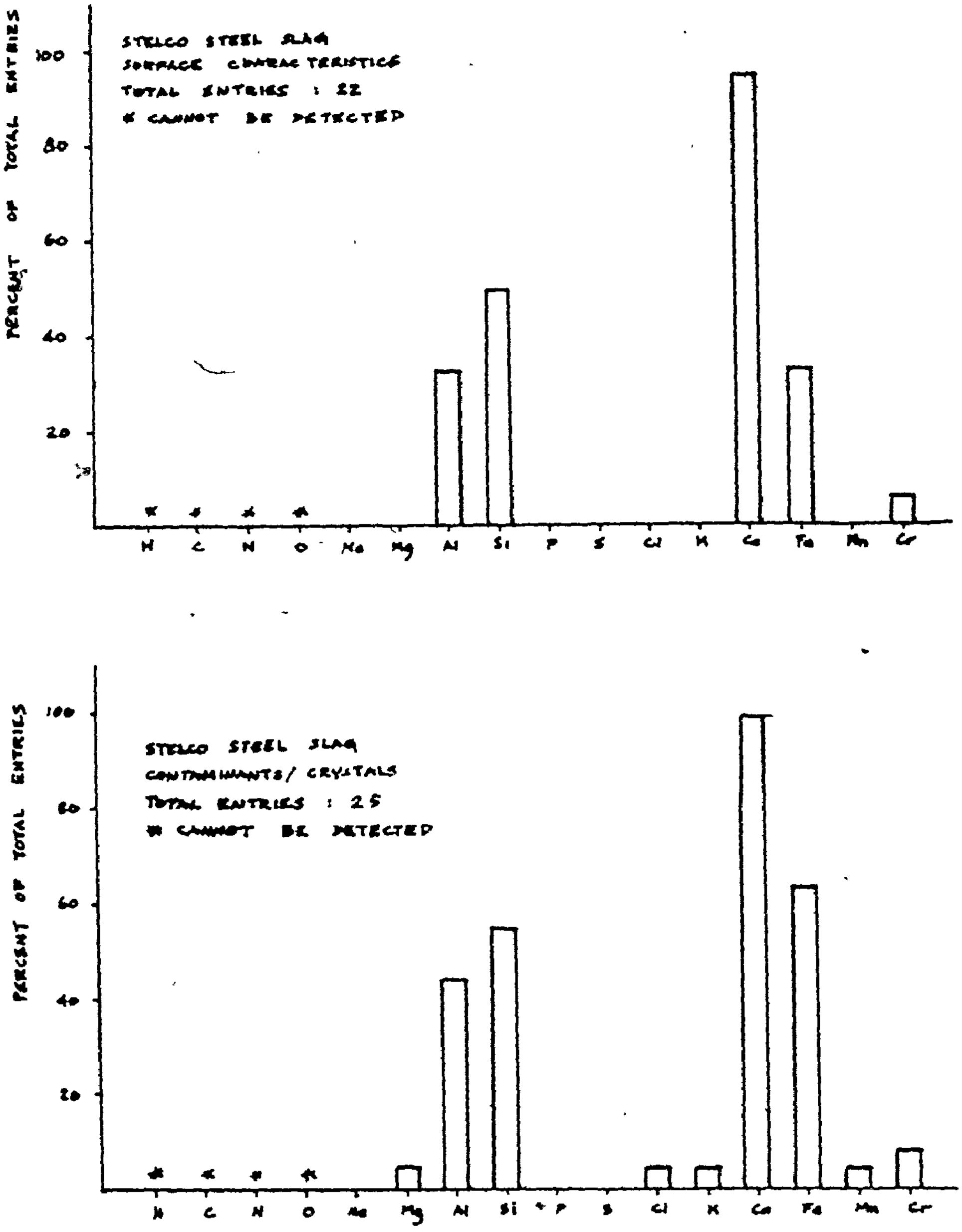


Figure E-2. Chemical Element Statistics for Stelco Steel Slag (Highway 401 Test Sections)

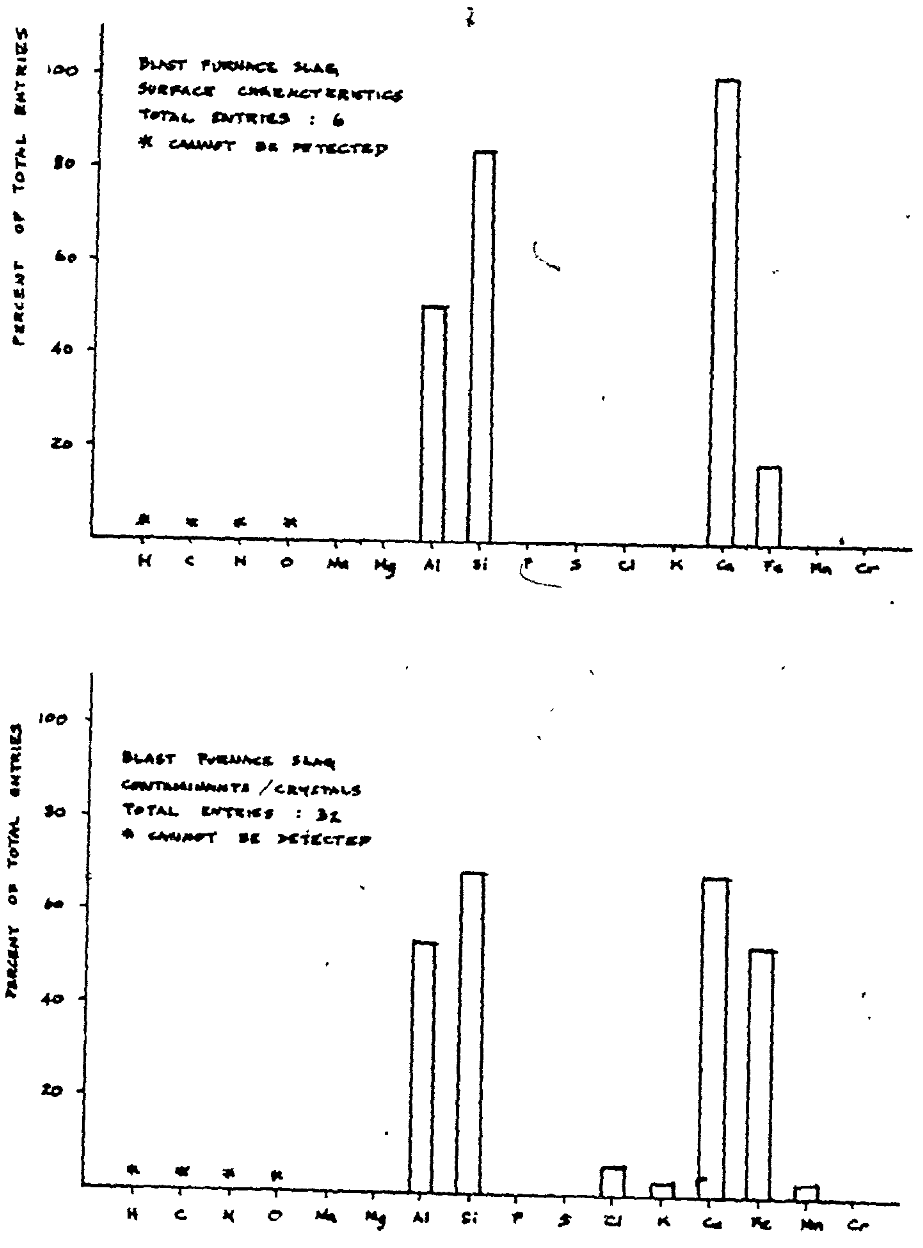


Figure E-3. Chemical Element Statistics for Blast Furnace Slag (Highway 401 Test Sections)

E.4 COMPLETE LISTING OF THE XRD ANALYSES

Table E-4 contains a complete listing of the XRD analysis as summarized in Tables E-1 to E-3 and Figures E-1 to E-4. For further explanation, see Appendix D.

Table E-4. Complete Listing of XRD Analyses of Core Samples from Highway 401 Test Sections

CIS1 - TR/990/SP-1

centroid adjustment : + 0.04

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	2.09 —	0.14	7064.47	92	113
2	1	3.56 Ca	0.14	11641.64	206	226
3	1	3.66 Ca	0.13	1572.49	230	251
4	1	6.15 Mn	0.12	1759.20	405	426
5	1	9.27 —	0.12	504.23	646	666

CIS1 - TR/9000/SP-2

centroid adjustment : + 0.04

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.22 Mg	0.13	1373.76	25	46
2	1	1.69 Si	0.13	2620.00	61	81
3	1	2.09 —	0.15	7055.73	92	113
4	1	3.56 Ca	0.14	4823.74	206	226
5	1	3.66 Ca	0.04	553.72	230	251
6	1	6.16 —	0.15	4065.22	406	426
7	1	6.78 Fe	0.10	466.96	453	474
8	1	9.27 —	0.17	1213.24	646	666

CIS1 - TR/2430/SP-3

centroid adjustment : + 0.04

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.70 Si	0.12	6913.70	62	83
2	1	2.10 —	0.15	3990.99	93	114
3	1	3.60 Ca	0.15	3095.97	208	229
4	1	6.22 Fe	0.14	4679.11	411	431
5	1	6.64 Fe	0.12	612.74	458	479
6	1	9.37 —	0.18	981.77	653	674

CIS1 - TR/2430/SP 4

centroid adjustment + 0.04

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1		1.22 Mg	0.09	706.01	27	44
2	1	1.70 Si	0.12	6060.96	62	63
3	1	2.10 —	0.14	6160.96	93	114
4	1	3.60 Ca	0.13	3056.20	208	229
5	1	6.22 Fe	0.12	4941.97	411	431
6	1	6.66 Fe	0.12	544.45	459	460
7	1	9.39 —	0.09	673.97	655	675

CIS1 - TR/2420/SP 5

centroid adjustment : + 0.04

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.22 Mg	0.09	648.03	26	46
2	1	1.71 Si	0.13	8450.59	63	63
3	1	2.10 —	0.14	5719.97	93	114
4	1	3.61 Ca	0.14	3153.21	209	230
5	1	6.23 Fe	0.16	4839.70	411	432
6	1	6.66 Fe	0.12	527.49	462	462
7	1	9.40 —	0.15	801.99	656	677

CIS2 - TR/480/SP-1

centroid adjustment : + 0.19

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1		1.31 Al	0.07	296.02	15	30
2	1	1.56 Si	0.12	3041.21	33	53
3	1	1.97 —	0.13	1262.47	65	65
4	1	3.51 Ca	0.12	964.65	186	206
5	1	6.21 Fe	0.14	1350.74	396	418
6	1	9.55 —	0.03	24.13	659	660

(continued)

C152 - TR/480/SP2

centroid adjustment + 0.16

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.00	—	0.16	2589.49	67	87
2	1	3.54	Ca	0.13	3463.46	168	209
3	1	3.86	Fe	0.13	353.73	214	234
4	1	6.22	Fe	0.10	175.38	399	419
5	1	6.72	—	0.03	-1.50	401	421
6	1	9.55	—	0.11	304.00	660	680

C152 - TR/480/SP3

centroid adjustment : + 0.16

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.00	—	0.15	1767.38	67	87
2	1	3.54	Ca	0.13	4978.86	168	208
3	1	3.66	Ca	0.15	816.48	213	234
4	1	9.56	—	0.18	469.71	661	681

C152 - TR/480/SP4

centroid adjustment : + 0.19

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.97	—	0.14	510.70	64	85
2	1	3.51	Ca	0.13	6014.66	166	206
3	1	3.63	Ca	0.13	957.95	211	232
4	1	6.19	Fe	0.03	204.91	396	416
5	1	6.20	Fe	0.02	10.66	398	418
6	1	9.54	—	0.05	152.47	658	679

C152 - TR/480/SP5

centroid adjustment : + 0.16

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.59	Si	0.14	652.47	34	55
2	1	2.00	—	0.11	2292.50	67	87
3	1	3.54	Ca	0.13	5009.99	166	206
4	1	3.66	Ca	0.10	550.49	213	234
5	1	9.56	—	0.12	370.46	661	682

C152 - TR/480/SP6

centroid adjustment : + 0.22

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.52	Si	0.12	6116.61		50
2	1	1.94	—	0.13	1901.20	62	83
3	1	9.50	—	0.08	362.00	656	676

C152 - TR/480/SP7

centroid adjustment : + 0.19

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.47	Si	0.14	195.00	27	46
2	1	1.97	—	0.14	2107.20	64	85
3	1	3.50	Ca	0.12	5256.10	165	205
4	1	3.63	Ca	0.10	660.73	210	231
5		9.51	—	0.08	225.38	659	675

C152 - TR/490/SP8

centroid adjustment : + 0.28

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.66	—	0.16	2345.20	57	78
2	1	3.42	Ca	0.14	5376.47	176	199
3		3.76	Ca	0.15	697.20	205	226
4		9.42	—	0.06	146.96	653	666

(continued)

C1S2 - TR/490/SP 9

centroid adjustment : + 0.19

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.50	Si	0.05	156.01	34	43
2	1	1.97	—	0.13	2357.25	64	85
3	1	3.50	Ca	0.14	5234.58	185	205
4	1	3.83	Ca	0.09	540.84	211	231
5	1	9.51	—	0.11	424.75	657	676

C1S2 - TR/490/SP 10

centroid adjustment : + 0 20

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.55	Si	0.11	409.48	32	52
2	1	1.96	—	0.18	1163.95	63	84
3	1	3.49	Ca	0.13	2745.20	184	205
4	1	3.83	Ca	0.08	351.83	210	230

C2S3 - TR/1000/SP 1

centroid adjustment : + 0.18

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.32	Al	0.10	1099.34	14	34
2	1	1.57	Si	0.06	191.74	34	55
3	1	2.00	—	0.10	133.36	67	87
4	1	3.52	Ca	0.14	1610.73	186	207
5		3.84	Ca	0.06	256.62	213	231
6	1	9.53	—	0.14	694.24	658	679

C2S3 - TR/1000/SP 2

centroid adjustment : + 0 20

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.26	Al	0.11	937.50	9	29
2	1	1.51	Si	0.11	2251.22	29	49
3	1	1.93	—	0.15	3196.24	62	82
4	1	3.47	Ca	0.13	688.23	183	203
5	1	6.15	Fe	0.08	133.63	392	412
6	1	9.48	—	0.15	576.49	654	674

C2S3 - TR/970/SP 3

centroid Adjustment : + 0 20

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.55	Si	0.13	625.96	32	51
2	1	1.96	—	0.17	2515.00	65	66
3	1	3.51	Ca	0.14	5649.23	186	206
4	1	3.65	Ca	0.13	761.71	212	233
5	1	9.51	—	0.15	346.46	657	677
6	1	11.29	—	0.07	140.03	797	817

C2S3 - TR/970/SP 4

centroid adjustment : + 0.20

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.56	Si	0.10	717.73	33	53
2	1	1.98	—	0.15	3459.74	65	86
3	1	3.52	Ca	0.13	3103.35	186	206
4	1	3.66	Ca	0.15	439.47	213	233
5	1	9.53	—	0.17	501.22	658	679

C2S3 - TR/970/SP 5

centroid Adjustment : + 0.20

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.29	Al	0.06	352.01	12	32
2	1	1.55	Si	0.11	752.99	31	52
3	1	1.97	—	0.14	2066.23	64	85
4	1	3.50	Ca	0.13	5707.22	165	205
5	1	3.82	Ca	0.14	534.74	211	231
6	1	9.52	—	0.11	456.96	657	678
7	1	12.82	—	0.03	45.26	918	938

(continued)

C254 - TR/200/TA 1

centroid adjustment : + 0.17

NC.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.58 Si	0.12	4552.09	34	54
2	1	1.99 —	0.15	3463.23	66	87
3	1	3.53 Ca	0.13	2722.47	187	208
4	1	3.86 Ca	0.03	211.72	212	233
5	1	6.24 Fe	0.09	386.22	399	420
6	1	9.54 —	0.09	419.35	659	679

C254 - TR/500/TA 2

centroid adjustment : + 0.17

NC.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.56 Si	0.12	3577.61	34	54
2	1	1.99 —	0.15	2266.71	66	67
3	1	3.53 Ca	0.14	2094.72	186	208
4		3.66 Ca	0.10	524.50	213	234
5	1	6.23 Fe	0.10	431.75	399	420
6	1	9.52 —	0.14	467.76	658	678
7	1	11.30 —	0.06	113.14	799	819

C254 - TR/500/TA 3

centroid adjustment : + 0.14

NC.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.60 Si	0.13	3064.23	36	56
2	1	2.02 —	0.15	2064.96	68	89
3	1	3.56 Ca	0.11	1963.35	190	210
4	1	6.27 Fe	0.06	391.97	402	423
5	1	9.56 —	0.09	250.46	661	681
6	1	11.30 —	0.06	28.86	801	821

C254 - TR/480/SP 4

centroid adjustment : +0.14

NC.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.60 Si	0.12	2650.21	35	56
2	1	2.02 —	0.12	660.73	69	89
3	1	3.55 Ca	0.13	1369.21	169	209
4		3.66 Ca	0.13	253.47	216	234
5	1	6.26 Fe	0.13	1139.96	401	422
6	1	9.54 —	0.05	264.65	660	660

C254 - TR/480/SP 5

centroid adjustment : + 0.15

NC.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	2.01 —	0.13	566.01	66	68
2	1	3.55 Ca	0.13	6644.46	169	209
3	1	3.87 Ca	0.08	665.47	214	235

C254 - TR/480/SP 6

centroid adjustment : + 0 15

NC.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1		1.34 Al	0.11	364.01	16	33
2	1	1.60 Si	0.12	2096.25	35	56
3	1	2.01 —	0.13	2870.34	66	86
4	1	3.14 K	0.09	274.77	156	176
5		3.54 Ca	0.08	224.15	169	207
6	1	9.56 —	0.12	383.96	661	662

C254 - TR/480/SP 7

centroid adjustment : +0 15

NC.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	2.01 —	0.16	2035.74	67	86
2	1	3.55 Ca	0.12	4313.49	169	209
3	1	3.86 Ca	0.12	454.06	215	235
4	1	9.55 —	0.12	292.53	660	681

C254 - TR/480/SP 8

centroid adjustment : + 0.15

NC.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.33 Al	0.10	1095.26	15	36
2	1	1.60 Si	0.13	5249.46	35	56
3	1	2.01 —	0.15	2650.22	66	66
4	1	3.55 Ca	0.11	391.06	169	209
5	1	9.55 --	0.04	266.52	660	660
6	1	9.58 —	0.03	240.85	664	664

(continued)

C354 - TR/480/SP9

centroid adjustment : + 0.14

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.35	Al	0.09	367.13	16	34
2	1	1.61	Si	0.11	1498.73	36	57
3	1	2.02	—	0.14	1574.49	69	89
4	1	3.56	Ca	0.12	1450.99	189	210
5	1	3.87	Ca	0.16	250.00	214	235
6	1	6.26	Fe	0.14	290.35	402	422
7	1	9.56	—	0.05	253.00	661	661

C355 - TR/2000/TA1

centroid adjustment : + 0.15

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.34	Al	0.08	816.79	16	34
2	1	1.60	Si	0.12	3527.70	35	56
3	1	2.01	—	0.13	2235.23	68	88
4		6.25	Fe	0.06	57.01	405	417
5	1	9.55	—	0.09	476.58	660	680

C355 - TR/1000/TA2

Centroid adjustment : + 0.17

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.33	Al	0.12	311.26	14	35
2	1	1.58	Si	0.09	868.47	33	54
3	1	1.99	—	0.11	1903.51	66	87
4	1	3.54	Ca	0.13	2679.59	188	208
5		3.88	Ca	0.10	322.98	215	234
6	1	6.24	Fe	0.13	315.72	400	420
7	1	9.53	—	0.08	263.75	656	678
8	1	11.23	—	0.12	116.63	793	813

C355 - TR/1000/TA3

centroid adjustment : + 0.16

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.32	Al	0.11	1202.52	14	35
2	1	1.59	Si	0.12	4221.64	35	55
3	1	2.00	—	0.13	2713.24	67	87
4	1	3.49	Ca	0.01	-27.23	166	209
5	1	9.55	—	0.15	479.46	660	681

C355 - TR/1080/SP4

centroid adjustment : + 0 16

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.58	Si	0.12	5214.23	34	55
2	1	2.00	—	0.13	2530.60	67	87
3	1	3.54	Ca	0.15	1630.63	166	208
4	1	3.66	Ca	0.06	261.99	212	233
5	1	6.24	Fe	0.11	916.09	400	420
6	1	9.55	—	0.11	455.64	660	680

C355 - TR/1080/SP5

Centroid adjustment + 0 16

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.30	Al	0.09	265.55	14	35
2	1	1.59	Si	0.12	3025.72	34	55
3	1	2.00	—	0.14	991.02	67	88
4	1	3.54	Ca	0.14	4540.09	188	206
5	1	3.66	Ca	0.09	496.56	213	233
6	1	9.56	—	0.13	279.13	662	682
7	1	11.29	—	0.05	68.54	795	816

C355 - TR/1080/SP6

Centroid adjustment : + 0.15

NO.	ECL	CENTROID		FWHM	ARFA	LFFT	RIGHT
1	1	1.34	Al	0.09	197.79	15	36
2	1	1.59	Si	0.13	1233.74	35	55
3	1	2.01	—	0.16	1190.73	67	88
4	1	3.54	Ca	0.13	1359.22	188	209
5	1	3.88	Ca	0.04	146.73	214	234
6	1	6.24	Fe	0.13	625.23	400	420
7	1	7.96	—	0.02	30.77	536	556
8	1	9.55	—	0.13	319.99	660	681

(continued)

C355 - TR/1080/SP7

centroid adjustment : + 0.17

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.29	Al	0.02	22.80	14	35
2		1.58	Si	0.13	528.00	35	54
3	1	1.99	—	0.15	2047.96	66	87
4	1	3.53	Ca	0.12	3130.99	167	208
5		3.85	Ca	0.10	362.97	213	232
6		4.36	Fe	0.02	48.49	256	270
7	1	9.55	—	0.12	504.25	660	681
8	1	11.34	—	0.04	159.74	801	821

C355 - TR/550/SP8

centroid adjustment : + 0.18

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.57	Si	0.14	2795.72	33	53
2	1	1.98	—	0.15	2167.99	65	86
3	1	3.52	Ca	0.12	1219.45	186	207
4	1	6.22	Fe	0.12	1114.70	396	419
5	1	9.52	—	0.10	311.75	658	679

C355 - TR/550/SP-9

centroid adjustment : + 0.18

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.30	Al	0.09	773.53	14	34
2	1	1.57	Si	0.13	4023.72	33	54
3	1	1.96	—	0.16	2556.46	65	86
4	1	9.51	—	0.04	301.76	657	676

C355 - TR/550/SP10

centroid adjustment : + 0.23

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.52	Si	0.02	639.25	29	50
2	1	1.93	—	0.12	1855.23	62	82
3	1	3.46	Ca	0.13	5322.85	163	203
4	1	3.81	Ca	0.14	550.24	206	229
5	1	6.16	Fe	0.04	106.00	396	417
6	1	9.47	—	0.01	19.95	657	676

C356 - TR/1200/TA-1

centroid adjustment : + 0.22

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.52	Si	0.04	179.61	33	45
2	1	1.94	—	0.14	2414.75	62	83
3	1	6.19	Fe	0.13	3371.06	396	416
4	1	6.84	Fe	0.12	343.09	447	467
5	1	9.46	—	0.15	399.99	654	675

C356 - TR/1200/TA-2

centroid adjustment : + 0.25

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Si	0.11	2256.96	27	46
2	1	1.91	—	0.15	2427.97	59	80
3	1	3.45	Ca	0.13	835.48	181	201
4	1	6.15	Fe	0.16	1461.72	393	413
5	1	9.45	—	0.12	442.21	652	673

C356 - TR/1400/TA3

centroid adjustment : + 0.26

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Si	0.11	2728.21	27	46
2	1	1.90	—	0.16	2726.23	59	80
3	1	3.44	Ca	0.14	950.73	160	201
4	1	6.14	Fe	0.13	911.23	392	413
5	1	9.44	—	0.14	406.70	651	672

C356 - TR/560/SP4

Centroid adjustment + 0.26

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Si	0.11	792.25	27	47
2	1	1.90	—	0.15	2246.74	59	79
3	1	3.44	Ca	0.13	1566.96	160	201
4	1	6.15	Fe	0.14	676.54	393	413
5	1	9.44	—	0.15	517.30	651	672

(continued)

C356 - TR/560/SP5

centroid adjustment . + 0.25

NC.	ECL.	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.91	—	0.15	2150.23	60	81
2	1	3.45	Ca	0.13	2709.73	181	201
3	1	3.77	Ca	0.10	279.56	206	226
4	1	9.49	—	0.11	224.61	655	675

C356 - TR/660/SP6

centroid adjustment + 0.28

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.47	Si	0.13	4344.96	25	46
2	1	1.66	—	0.18	1197.74	58	78
3	1	3.42	Ca	0.14	1322.35	179	199
4	1	3.76	Ca	0.06	160.84	207	227
5	1	6.12	Fe	0.16	1192.63	391	411
6	1	6.79	Fe	0.10	200.98	442	463
7	1	6.81	Fe	0.09	154.72	446	466
8	1	9.42	—	0.15	391.16	650	670

C356 - TR/660/SP7

centroid adjustment : + 0.26

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.22	Al	0.10	597.02	7	27
2	1	1.49	Si	0.12	4233.74	27	48
3	1	1.90	—	0.13	2619.00	59	80
4	1	6.27	—	0.04	136.46	560	580
5	1	9.46	—	0.12	386.47	653	673

C356 - TR/1200/SP8

centroid adjustment . + 0 24

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.25	Al	0.05	164.78	7	28
2	1	1.51	Si	0.03	126.23	27	46
3	1	1.92	—	0.01	333.30	60	81
4	1	6.18	Fe	0.16	4965.24	395	416
5	1	6.83	Fe	0.15	756.64	447	467
6	1	9.47	—	0.12	549.00	654	675

C356 - TR/1200/SP9

centroid adjustment : + 0 27

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.69	—	0.15	2664.23	56	79
2	1	6.13	Fe	0.16	3655.20	391	412
3	1	6.76	Fe	0.13	364.70	442	463
4	1	9.42	—	0.10	205.54	651	671

C457 - TR/500/TA1

centroid adjustment . + 0.05

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.44	Al	0.12	1460.40	24	42
2	1	1.70	Si	0.18	5902.49	43	64
3	1	2.11	—	0.14	3734.72	76	96
4	1	3.67	Ca	0.07	300.25	196	218
5	1	6.52	Fe	0.03	-14.77	413	434
6	1	9.70	—	0.15	509.75	672	692

C457 - TR/1100/TA3

centroid adjustment . + 0.04

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.44	Al	0.10	543.17	23	44
2	1	1.71	Si	0.11	2690.23	44	65
3	1	2.12	—	0.12	1650.63	76	96
4	1	3.26	K	0.11	616.99	166	186
5	1	3.66	Ca	0.13	1652.24	197	218
6	1	6.37	Fe	0.13	765.77	410	431
7	1	9.70	—	0.16	260.73	672	692

C457 - TR/1000/TA2

centroid adjustment . + 0 04

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.44	Al	0.11	1449.77	23	43
2	1	1.70	Si	0.11	2539.22	44	64
3	1	2.11	—	0.14	2176.73	76	96
4	1	3.66	Ca	0.13	2563.47	197	216
5	1	6.36	Fe	0.13	701.54	409	430
6	1	9.70	—	0.16	404.65	672	692

(continued)

C457 - TR/1190/SP4

centroid adjustment : + 0.04

NC.	ECL	CENTRCID		FWHM	AREA	LEFT	RIGHT
1	1	1.45	Al	0.11	5367.00	24	44
2	1	1.71	Si	0.10	521.36	45	65
3	1	2.12	—	0.13	1351.75	77	97
4		3.65	Ca	0.05	66.54	196	215
5	1	9.66	—	0.11	506.00	670	691

C457 - TR/1190/SP5

centroid adjustment : + 0.05

NC.	ECL	CENTRCID		FWHM	AREA	LEFT	RIGHT
1	1	1.37	Al	0.11	113.76	23	43
2	1	1.71	Si	0.10	4526.49	44	64
3	1	2.11	—	0.15	3026.24	76	96
4	1	3.66	Ca	0.13	735.63	196	218
5	1	4.50	—	0.02	226.22	264	284
6	1	6.37	Fe	0.12	340.99	410	431
7	1	9.67	—	0.11	281.74	670	690

C457 - TR/1190/SP6

Centroid adjustment : + 0.04

NC.	ECL	CENTRCID		FWHM	AREA	LEFT	RIGHT
1		1.44	Al	0.10	611.04	25	42
2	1	1.70	Si	0.13	2974.45	43	64
3	1	2.12	—	0.14	2537.22	76	96
4	1	3.67	Ca	0.06	217.25	197	217
5	1	4.50	—	0.02	52.71	260	280
6	1	6.37	Fe	0.10	1104.97	410	431
7		6.99	Fe	0.11	92.76	456	476
8	1	9.69	—	0.10	235.96	671	691

C457 - TR/1190/SP7

centroid adjustment : + 0.03

NC.	ECL	CENTRCID		FWHM	AREA	LEFT	RIGHT
1	1	1.44	Al	0.12	6119.46	23	44
2	1	1.71	Si	0.09	543.71	44	65
3	1	2.11	—	0.09	941.23	75	96
4	1	3.64	Ca	0.01	151.70	196	217
5	1	6.34	Fe	0.06	161.26	406	429
6	1	9.61	—	0.01	-16.23	667	687
7	1	13.31	—	0.03	120.68	955	975

C457 - TR/1190/SP8

centroid adjustment . + 0.04

NC.	ECL	CENTRCID		FWHM	AREA	LEFT	RIGHT
1	1	1.44	Al	0.13	5195.47	23	44
2		1.71	Si	0.09	169.22	46	63
3	1	2.10	—	0.12	747.42	75	95
4	1	2.95	—	0.04	93.54	143	163
5	1	3.65	Ca	0.11	440.49	197	218
6	1	4.50	—	0.07	93.66	263	283
7	1	6.36	Fe	0.13	-258.74	409	429
8	1	9.67	—	0.13	159.09	670	690
9	1	9.70	—	0.09	155.10	674	694
10	1	11.52	—	0.01	-65.53	815	835

C457 - TR/1190/SP9

centroid adjustment : + 0.05

NC.	ECL	CENTRCID		FWHM	AREA	LEFT	RIGHT
1		1.44	Al	0.06	209.01	26	39
2	1	1.71	Si	0.06	376.66	44	64
3	1	2.11	—	0.16	1666.23	76	96
4	1	3.66	Ca	0.13	6751.47	196	216
5	1	3.99	Ca	0.12	705.70	224	245
6	1	6.37	Fe	0.03	167.23	409	430
7		6.72	Fe	0.03	30.49	443	453
8	1	9.66	—	0.02	310.23	670	690

C457 - TR/1190/SP10

Centroid adjustment : + 0.04

NC.	ECL	CENTRCID		FWHM	AREA	LEFT	RIGHT
1	1	1.44	Al	0.12	4343.20	23	44
2	1	1.69	Si	0.01	-32.05	44	65
3	1	2.12	—	0.13	455.97	77	97
4	1	2.98	—	0.02	86.16	143	163
5	1	3.66	Ca	0.10	329.70	197	218
6		6.36	Fe	0.02	95.00	409	429

(continued)

C457 - TR/1190/SP 11

centroid adjustment : + 0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.44	Al	0.11	4303.96	23	44
2	1	1.71	Si	0.02	275.70	44	65
3	1	2.10	—	0.10	734.17	75	95
4	1	3.66	Ca	0.13	360.46	197	218
5	1	4.46	—	0.06	60.00	260	260
6	1	6.37	Fe	0.06	256.35	410	430
7	1	9.69	—	0.14	262.45	671	692

C458 - TR/550/TA 1

centroid adjustment : + 0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.11	—	0.17	2900.30	75	96
2	1	5.86	Cr	0.14	619.47	370	391
3	1	6.36	Fe	0.14	3317.49	409	430
4	1	7.01	Fe	0.11	441.23	460	481
5	1	9.65	—	0.01	272.15	668	668

C458 - TR/1100/TA 2

centroid adjustment : + 0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.12	—	0.14	2665.97	76	97
2	1	5.86	Mn	0.10	793.11	370	390
3	1	6.37	Fe	0.15	3094.00	410	431
4	1	7.02	Fe	0.14	362.46	461	482
5	1	9.66	—	0.06	299.34	671	691

C458 - TR/1100/TA 3

centroid adjustment : + 0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.05	110.61	24	44
2	1	2.10	—	0.04	300.77	74	95
3	1	5.36	Cr	0.04	120.53	332	353
4	1	5.67	Cr	0.15	1001.97	371	392
5	1	6.36	Fe	0.16	4696.11	410	430
6	1	7.03	Fe	0.16	596.95	461	482
7	1	9.67	—	0.13	376.34	670	690

C458 - TR/1100/TA 4

centroid adjustment : + 0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.11	—	0.13	2539.75	75	96
2	1	5.36	Cr	0.06	235.70	330	351
3	1	5.66	Cr	0.14	775.74	370	391
4	1	6.36	Fe	0.13	2663.49	409	430
5	1	7.02	Fe	0.12	366.70	461	482
6	1	9.66	—	0.16	522.13	670	690

C458 - TR/830/SP 5

centroid adjustment : + 0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.19	Mg	0.06	202.75	4	25
2	1	2.12	—	0.15	1567.00	76	97
3	1	3.66	Ca	0.13	5298.10	197	217
4	1	3.96	Ca	0.10	696.66	224	244
5	1	6.36	Fe	0.04	404.36	410	430
6		9.66	—	0.15	304.00	670	688

C458 - TR/830/SP 6

centroid adjustment : + 0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.44	Al	0.17	510.02	23	44
2	1	2.11	—	0.15	3117.10	76	96
3	1	3.66	Ca	0.12	3445.36	197	217
4		3.96	Ca	0.11	469.74	223	241
5	1	6.37	Fe	0.06	203.46	409	430
6	1	9.66	—	0.01	554.74	670	691

C458 - TR/830/SP 7

centroid adjustment : + 0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.45	Al	0.11	403.52	27	40
2	1	1.70	Si	0.11	2510.46	43	64
3	1	2.12	—	0.14	2567.97	76	97
4	1	3.65	Ca	0.13	2610.66	197	217
5	1	3.97	Ca	0.11	492.35	222	242
6	1	6.36	Fe	0.07	63.76	407	427
7	1	6.36	Fe	0.07	146.29	410	431
8	1	9.65	—	0.11	401.39	666	686

(continued)

C488 - TR/830/SP 8

centroid adjustment : + 0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.34	—	0.08	73.03	23	44
2	1	2.11	—	0.15	2970.33	76	96
3	1	3.65	Ca	0.14	2105.13	197	217
4	1	5.86	Mn	0.09	264.23	370	390
5	1	6.37	Fe	0.15	962.50	410	431
6	1	9.68	—	0.16	473.25	671	691

C559 - TR/1080/TA 1

centroid adjustment : - 0.02

ITIPCENTROID				FWHM	AREA	LEFT	RIGHT
1	1	1.26	Mg	0.09	596.13	11	31
2	1	1.77	Si	0.12	4201.46	49	69
3	1	2.16	—	0.15	4076.09	61	101
4	1	3.72	Ca	0.14	1393.23	202	223
5	1	4.25	—	0.01	-6.01	229	249
6	1	6.43	Fe	0.12	655.75	415	435
7		7.05	Fe	0.00	-11.13	472	476
6	1	9.73	—	0.17	666.99	674	695

C559 - TR/2200 - TA 2

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.06	794.26	26	46
2	1	1.77	Si	0.11	1746.96	49	69
3	1	2.16	—	0.18	2546.34	61	101
4	1	3.72	Ca	0.13	1596.97	202	223
5		4.06	Ca	0.13	217.09	230	246
6	1	6.43	Fe	0.12	428.75	415	436
7	1	9.72	—	0.15	406.71	674	694

C559 - TR/420/SP4

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.77	Si	0.11	7306.75	49	69
2	1	2.16	—	0.15	3951.73	61	101
3	1	9.72	—	0.12	246.64	674	694

C559 - TR/420/SP 3

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.51	Al	0.11	202.30	30	51
2	1	1.77	Si	0.10	546.26	49	69
3	1	2.16	—	0.16	2360.75	61	102
4	1	3.73	Ca	0.12	2369.61	203	223
5	1	4.05	Ca	0.07	220.97	226	246
6	1	4.07	Ca	0.01	13.72	229	249
7	1	4.07	Ca	0.06	211.66	232	252
6	1	9.74	—	0.13	506.70	674	695

C559 - TR/420/SP 5

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Al	0.10	1151.51	26	49
2	1	1.76	Si	0.12	4637.22	46	69
3	1	2.16	—	0.16	3654.10	61	101
4	1	3.72	Ca	0.16	453.96	202	223
5	1	9.73	—	0.10	463.22	674	694

C559 - TR/420/SP 6

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.77	Si	0.12	6222.00	49	69
2	1	2.16	—	0.16	3070.56	61	101
3	1	9.74	—	0.15	526.45	675	696

C559 - TR/420/SP 7

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.12	765.41	26	46
2	1	1.76	Si	0.12	1640.03	46	69
3	1	2.16	—	0.15	3366.09	61	101
4	1	3.72	Ca	0.13	1509.46	202	223
5	1	4.05	Ca	0.12	161.50	229	249
6	1	6.44	Fe	0.09	211.50	416	437
7	1	9.74	—	0.14	715.36	675	695
8	1	11.49	—	0.06	121.01	812	833
9		12.72	—	0.03	-2.47	816	834

(continued)

CS59 - TR/420/SP8

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.06	276.27	29	49
2	1	1.75	Si	0.10	450.64	48	66
3	1	2.16	—	0.14	3482.75	61	102
4	1	3.72	Ca	0.12	2924.97	202	222
5	1	6.43	Fe	0.13	407.46	415	435
6	1	9.73	—	0.07	446.45	674	695

CS510 - TR/1200/TA1

centroid adjustment : - 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.11	1063.79	26	49
2	1	1.77	Si	0.11	2405.63	49	69
3	1	2.17	—	0.16	3305.97	60	101
4	1	3.72	Ca	0.13	2005.95	202	223
5	1	4.06	Ca	0.04	90.96	229	250
6	1	6.43	Fe	0.15	602.72	415	436
7	1	9.72	—	0.12	447.30	673	694

CS510 - TR/1200/TA2

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.77	Si	0.10	1737.34	49	69
2	1	2.16	—	0.17	3566.95	61	102
3	1	3.72	Ca	0.14	1612.24	202	223
4	1	4.05	Ca	0.12	324.61	226	246
5	1	6.42	Fe	0.12	425.53	414	435
6	1	9.74	—	0.12	307.23	675	695

CS810 - TR/1200/TA3

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.06	616.00	26	49
2	1	1.76	Si	0.12	2390.23	48	69
3	1	2.16	—	0.15	3467.23	61	102
4	1	3.72	Ca	0.14	1600.49	202	223
5	1	4.04	Ca	0.09	266.09	226	246
6	1	6.43	Fe	0.12	719.09	415	435
7	1	9.73	—	0.07	219.24	674	694

CS510 - TR/500/SP4

centroid adjustment . - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.33	Mg	0.06	96.30	12	33
2	1	1.76	Si	0.11	534.22	49	70
3	1	2.16	—	0.14	2567.74	61	102
4	1	3.72	Ca	0.13	4219.21	202	223
5	1	9.73	—	0.05	350.99	674	694

CS510 - TR/800/SP5

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.11	854.53	26	49
2	1	1.77	Si	0.12	2165.72	49	69
3	1	2.16	—	0.12	1031.99	61	102
4	1	3.72	Ca	0.12	2016.46	202	223
5	1	6.43	Fe	0.09	599.21	415	436
6	1	9.73	—	0.16	394.72	675	695

CS510 - TR/1300/SP6

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.07	334.04	26	49
2	1	1.76	Si	0.12	5166.20	48	69
3	1	2.16	—	0.15	4065.38	61	101
4	1	3.72	Ca	0.08	51.01	200	221
5	1	6.42	Fe	0.02	150.56	416	436
6	1	9.71	—	0.17	566.96	674	695
7		11.43	—	0.07	53.66	810	826

CS810 - TR/2600/SP7

centroid adjustment : - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.28	Mg	0.09	629.54	11	32
2		1.53	Al	0.04	150.77	34	47
3	1	1.78	Si	0.10	373.53	49	70
4	1	2.16	—	0.16	3135.23	61	102
5	1	3.72	Ca	0.13	2497.96	202	223
6	1	4.06	Ca	0.09	325.13	229	249
7	1	6.42	Fe	0.05	164.23	415	435
8	1	9.73	—	0.09	463.71	674	694

(continued)

C5S10 - TR / 2600 / SP 8

centroid adjustment : - 0 02

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1		1.72 Si	0.06	26.13	52	60
2	1	1.76 Si	0.16	673.47	46	69
3	1	2.16 —	0.15	3476.00	81	102
4	1	3.72 Ca	0.13	2907.46	202	223
5	1	6.41 Fe	0.14	246.77	414	434
6	1	9.72 —	0.14	465.70	673	694

C6S11 - TR / 2200 / TA 1

centroid adjustment : 0 0

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.48 Al	0.12	249.53	27	48
2	1	1.76 Si	0.11	2171.25	46	69
3	1	2.17 —	0.14	2644.22	80	101
4	1	3.71 Ca	0.11	685.71	202	222
5	1	4.02 Ca	0.15	265.84	226	246
6	1	6.41 Fe	0.14	967.22	414	434
7	1	7.05 Fe	0.16	209.77	464	485
8	1	9.71 —	0.06	405.34	673	693

C6S11 - TR/ 5500 / TA 2

centroid adjustment - 0 01

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.25 Mg	0.08	229.64	10	30
2	1	1.46 Al	0.07	154.92	26	46
3	1	1.76 Si	0.12	3291.47	48	69
4	1	2.17 —	0.15	3542.20	60	101
5	1	3.71 Ca	0.10	1066.23	202	222
6	1	6.42 Fe	0.14	1099.96	414	435
7	1	9.78 —	0.13	453.22	673	694

C6S11 - TR / 2600 / SP 3

centroid adjustment - 0 01

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1		1.26 Mg	0.06	403.63	12	28
2	1	1.47 Al	0.06	275.76	26	48
3	1	1.76 Si	0.12	3195.21	46	66
4	1	2.17 —	0.16	3363.70	60	101
5	1	3.71 Ca	0.13	1034.75	201	222
6	1	6.41 Fe	0.12	799.64	414	434
7	1	9.73 —	0.10	372.48	674	695

C6S11 - TR / 2600 / SP 4

centroid adjustment : - 0.02

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.76 Si	0.17	1450.26	46	69
2	1	2.18 —	0.14	3419.97	81	102
3	1	3.71 Ca	0.11	940.77	201	222
4	1	4.03 Ca	0.10	259.11	227	247
5	1	4.55 —	0.16	542.97	267	266
6	1	6.42 Fe	0.06	249.47	413	434
7	1	9.73 —	0.16	508.49	674	695

C6S11 - TR / 2600 / SP 5

centroid adjustment : - 0.01

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.26 Mg	0.06	335.26	9	30
2	1	1.97 —	0.07	-19.20	27	46
3	1	1.76 Si	0.13	2720.24	46	69
4	1	2.17 —	0.15	3212.45	80	101
5	1	3.71 Ca	0.12	2490.73	201	222
6	1	6.40 Fe	0.09	182.70	414	435
7	1	9.69 —	0.11	505.30	671	692

C6S11 - TR / 2600 / SP 6

centroid adjustment : - 0.10

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1		1.26 Mg	0.07	95.00	12	28
2	1	1.76 Si	0.11	2374.97	46	69
3	1	2.17 —	0.13	3234.96	60	101
4	1	3.72 Ca	0.13	670.59	202	222
5	1	4.03 Ca	0.18	215.76	227	247
6	1	6.41 Fe	0.15	744.86	413	433
7	1	9.73 —	0.13	557.72	674	695
8	1	11.47 —	0.14	260.76	811	831

C6S12 - TR / 1000 / TA 1

Centroid adjustment : - 0 01

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.49 Al	0.09	1120.53	27	46
2	1	1.76 Si	0.13	4950.50	46	69
3	1	2.17 —	0.14	3702.47	60	100
4	1	9.71 —	0.09	374.46	672	693

(continued)

C6S12 - TR/1000/TA2

centroid adjustment : - 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.49	Al	0.18	1397.01	27	48
2	1	1.76	Si	0.12	4993.21	48	69
3	1	2.17	—	0.14	3156.36	60	100
4	1	3.72	Ca	0.01	-46.23	200	221
5	1	9.72	—	0.16	694.99	673	694

C6S12 - TR/2000/SP3

centroid adjustment : - 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.50	Al	0.10	757.04	28	47
2	1	1.76	Si	0.11	2465.75	46	69
3	1	2.17	—	0.14	3640.97	60	101
4	1	3.71	Ca	0.12	1060.34	202	222
5		6.39	Fe	0.02	93.36	416	426
6	1	6.41	Fe	0.06	271.22	414	434
7	1	9.70	—	0.11	466.54	672	693

C6S12 - TR/2000/SP4

centroid adjustment : - 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.27	Mg	0.10	296.27	10	31
2		1.52	Al	0.15	606.64	30	48
3	1	1.76	Si	0.10	1246.29	45	68
4	1	2.17	—	0.14	3724.22	60	101
5	1	3.72	—	0.13	1226.23	202	223
6	1	6.43	Ca	0.12	621.59	415	435
7	1	9.71	Fe	0.12	541.09	673	693
6	1	12.30	—	0.01	13.00	876	896

C6S12 - TR/2000/SP5

centroid adjustment : - 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.50	Al	0.08	623.88	30	46
2		1.76	Si	0.11	895.72	50	67
3	1	2.17	—	0.14	3436.20	60	101
4	1	3.71	Ca	0.13	1467.46	201	222
5	1	9.73	—	0.13	395.22	674	695
6	1	11.45	—	0.14	250.53	809	629
7	1	11.49	—	0.09	198.64	613	833

C6S12 - TR/2000/SP6

centroid adjustment : - 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.09	336.27	26	46
2	1	1.76	Si	0.10	670.22	46	69
3	1	2.17	—	0.13	2712.34	60	100
4	1	3.71	Ca	0.13	1468.50	201	222
5	1	6.42	Fe	0.14	456.35	414	434
6	1	9.73	—	0.08	364.72	674	695
7	1	11.52	—	0.01	9.17	807	827
8	1	12.89	—	0.02	7.25	913	933

C14S25 - TR/520/SP1

centroid adjustment : + 0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.21	Mg	0.06	521.69	50	70
2	1	1.71	Si	0.12	5540.96	86	107
3	1	2.13	—	0.17	5072.73	116	137
4	1	3.67	Ca	0.14	1966.23	229	250
5	1	6.31	Fe	0.14	1979.22	423	443
6	1	6.66	Fe	0.09	375.77	464	485

C14S25 - TR/520/SP2

centroid adjustment : + 0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.71	Si	0.13	7206.59	86	106
2	1	2.13	—	0.15	7194.47	116	137
3	1	3.66	Ca	0.08	359.46	229	249
4	1	6.31	Fe	0.15	1744.66	423	443

C14S25 - TR/520/SP3

centroid adjustment : + 0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.71	Si	0.11	1672.27	86	106
2	1	2.13	—	0.16	5426.63	117	137
3	1	2.62	—	0.03	449.50	152	173
4	1	3.67	Ca	0.13	565.46	230	250
5	1	6.32	Fe	0.16	1304.49	423	444
6	1	9.36	—	0.12	201.35	649	669

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C14525 - TR/1025/SP4

centroid adjustment : + 0.03

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.21	Mg	0.11	678.30	49	70
2	1	1.58	Al	0.03	32.30	84	105
3	1	2.13	—	0.16	5789.00	116	137
4	1	3.67	Ca	0.13	2113.46	230	250
5	1	6.31	Fe	0.13	1022.73	423	443
6		9.32	—	0.09	194.98	647	668

C14525 - TR/1025/SP5

centroid adjustment : + 0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.70	Si	0.11	654.03	85	106
2	1	2.13	—	0.17	6534.74	116	137
3	1	3.67	Ca	0.13	1416.96	230	250
4	1	6.31	Fe	0.17	1666.38	423	443
5	1	10.58	—	0.10	191.50	731	751

C14625 - TR/5100/SP6

centroid adjustment : + 0 03

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.69	Si	0.16	860.76	84	105
2	1	2.13	—	0.16	7054.49	116	137
3	1	3.67	Ca	0.14	1505.00	229	250
4	1	6.30	Fe	0.04	1498.97	423	443

C14526 - TR/970/SP1

centroid adjustment : + 0 03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.72	Si	0.13	6858.23	86	107
2	1	2.13	—	0.14	5056.98	117	137
3	1	6.30	Fe	0.13	863.38	422	442

C14526 - TR/970/SP2

centroid adjustment : + 0 03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.71	Si	0.13	8615.45	86	107
2	1	2.13	—	0.16	2995.73	116	137
3	1	3.66	Ca	0.11	368.09	229	249
4	1	6.31	Fe	0.19	1770.09	423	443

C14526 - TR/970/SP3

centroid adjustment : + 0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.09	157.30	67	88
2	1	2.13	—	0.14	1841.09	117	137
3		3.70	Ca	0.02	-48.09	231	249
4	1	6.30	Fe	0.17	2413.71	422	443

C14526 - TR/970/SP4

centroid adjustment : + 0 03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.21	Mg	0.11	435.50	49	70
2	1	1.71	Si	0.13	3236.23	86	107
3	1	2.13	—	0.16	5455.96	116	137
4	1	3.66	Ca	0.14	1128.23	229	249
5	1	6.30	Fe	0.19	2252.75	422	443
6		6.95	Fe	0.07	127.00	474	466

C14526 - TR/970/SP6

centroid adjustment : + 0 03

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.40	Mg	0.10	474.00	50	71
2		1.70	Si	0.14	567.26	84	105
3	1	2.13	—	0.15	6466.96	116	137
4	1	3.66	Ca	0.12	2117.59	229	249
5	1	3.98	Ca	0.08	350.83	253	273
6	1	6.30	Fe	0.15	1229.38	422	442
7		9.37	—	0.09	329.97	649	667

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C14526 - TR/970/AR5
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.46	Al	0.09	653.01	70	85
2	1	1.71	Si	0.13	4787.98	86	107
3	1	2.13	—	0.16	5866.70	116	137
4		3.67	Ca	0.17	531.72	230	251
5	1	6.31	Fe	0.16	1325.33	423	443

C14526 - TR/970/SP7
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.20	Mg	0.12	248.02	58	67
2		1.45	Al	0.05	546.13	70	84
3	1	1.71	Si	0.13	1884.15	86	106
4	1	2.13	—	0.15	6612.22	116	137
5	1	3.67	Ca	0.13	417.63	229	249
6	1	6.30	Fe	0.19	1765.70	422	443

C15527 - TR/570/SP1
centroid adjustment : +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.69	Si	0.12	923.25	56	77
2	1	2.11	—	0.15	6635.45	86	107
3	1	3.65	Ca	0.13	5288.48	201	222
4	1	6.37	Fe	0.15	2075.13	404	424
5	1	9.65	—	0.18	1642.47	648	669

C15527 - TR/570/SP2
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.45	Al	0.12	2452.50	38	56
2	1	1.70	Si	0.13	2147.99	56	76
3	1	2.12	—	0.15	1173.45	86	107
4	1	6.36	Fe	0.16	4937.99	403	424
5	1	9.66	—	0.11	1258.34	649	669

C15527 - TR/1140/SP3
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.45	Al	0.11	2939.49	37	58
2	1	6.37	Fe	0.14	4794.33	404	424
3	1	7.01	Fe	0.08	510.74	452	473

C15527 - TR/1140/SP4
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.45	Al	0.11	2218.23	37	58
2	1	6.37	Fe	0.15	3001.20	404	425

C15527 - TR/2280/SP5
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.45	Al	0.11	1663.04	38	56
2	1	2.11	—	0.15	2562.74	86	106
3	1	3.65	Ca	0.12	573.75	202	222
4	1	6.36	Fe	0.15	3851.24	403	424
5	1	7.01	Fe	0.14	560.49	451	471
6	1	9.68	—	0.18	818.98	650	671

C15527 - TR/2280/SP6
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.11	1838.66	38	58
2	/ 1	2.07	—	0.15	2045.85	83	103
3	/ 1	6.36	Fe	0.15	3034.46	403	424

C15527 - TR/2280/SP7
centroid adjustment : +0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.45	Al	0.13	2876.46	37	58
2	1	6.37	Fe	0.14	4107.49	403	424

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CIS $28 - TR/2200/SP1
centroid adjustment . +0.03

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	2.13 —	0.16	10209.46	87	108
2	1	3.68 Ca	0.14	2431.33	203	223
3	1	6.37 Fe	0.12	604.39	404	424
4	1	9.66 —	0.19	1354.96	649	669

CIS $28 - TR/2200/SP2
centroid adjustment : +0.02

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.72 Si	0.15	3680.21	57	77
2	1	2.14 —	0.16	9888.75	68	109
3	1	3.66 Ca	0.14	701.86	200	220
4	1	3.69 Ca	0.15	1154.47	203	224
5	1	6.36 Fe	0.16	1266.66	405	425
6	1	9.67 —	0.13	1230.22	649	670

CIS $28 - TR/2200/SP3
centroid adjustment : +0.02

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.71 Si	0.12	1451.54	56	77
2	1	2.14 —	0.17	3070.72	88	109
3	1	3.66 Ca	0.16	1202.59	203	223
4	1	6.38 Fe	0.14	2517.96	405	425
5	1	9.67 —	0.16	1468.46	650	670

CIS $28 - TR/2200/SP4
centroid adjustment : +0.04

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.70 Si	0.14	5160.33	56	76
2	1	2.12 —	0.16	10236.71	87	108
3	1	3.67 Ca	0.14	2892.46	202	223
4	1	6.37 Fe	0.16	2137.10	404	424
5	1	9.66 —	0.18	1322.00	649	669

CIS $28 - TR 2200/SP5
centroid adjustment . +0.05

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.69 Si	0.14	2015.76	55	76
2	1	2.11 —	0.16	12295.49	86	107
3	1	6.36 Fe	0.15	1244.84	403	423
4	1	9.65 —	0.15	1566.46	646	669

(continued)

C7813 - SS/1000/TA-1
centroid adjustment : +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.11	—	0.14	3054.78	75	96
2	1	3.66	Ca	0.13	2930.84	197	216
3	1	3.96	Ca	0.08	378.98	223	244
4	1	9.63	—	0.01	189.41	666	666
5	1	9.72	—	0.15	306.84	674	694

C7813 - SS/1100/TA-2
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.12	—	0.15	3262.70	76	97
2	1	3.65	Ca	0.12	2961.74	197	217
3	1	3.98	Ca	0.13	369.48	223	243
4	1	9.66	—	0.12	316.75	669	690

C7813 - SS/2100/TA-3
centroid adjustment : +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.65	Si	0.07	283.51	40	60
2	1	2.11	—	0.13	2201.73	76	96
3	1	3.65	Ca	0.13	3140.96	197	217
4		3.97	Ca	0.09	330.47	222	242
5	1	9.65	—	0.08	460.40	668	688

C7813 - SS/475/SP-4
centroid adjustment +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.70	Si	0.12	7666.46	43	64
2	1	2.11	—	0.13	3016.08	76	96
3	1	3.66	Ca	0.14	966.33	197	217
4	1	6.37	Fe	0.05	183.08	411	431
5	1	9.67	—	0.02	255.61	670	690

C7813 - SS/475/SP-5
centroid adjustment +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.11	—	0.15	2852.73	76	96
2	1	3.65	Ca	0.12	3158.75	197	217
3		3.96	Ca	0.11	360.22	224	248
4	1	9.62	—	0.08	260.14	665	685
5		9.62	—	0.01	-2.38	677	681

C7813 - SS/475/SP-6
centroid adjustment +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.43	Al	0.02	139.52	26	40
2	1	1.69	Si	0.09	647.64	43	63
3	1	2.11	—	0.15	3654.06	76	96
4	1	3.65	Ca	0.13	2507.13	197	217
5		3.97	Ca	0.11	306.98	224	241
6	1	6.44	Zn	0.03	-70.54	573	593
7	1	9.66	—	0.14	302.74	669	690

C7813 - SS/475/SP-7
centroid adjustment +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.71	Si	0.11	1173.14	44	64
2	1	2.12	—	0.14	1146.35	77	97
3	1	3.66	Ca	0.13	3653.75	197	217
4	1	3.99	Ca	0.12	435.74	224	244
5	1	9.65	—	0.09	169.00	666	686

C7813 - SS/475/SP-8
centroid adjustment : +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.44	Al	0.09	491.76	26	40
2	1	1.70	Si	0.11	4220.98	43	64
3	1	2.11	—	0.13	2459.99	76	96
4	1	3.66	Ca	0.13	1371.72	197	218
5	1	6.36	Fe	0.16	1046.74	410	430
6	1	6.96	Fe	0.03	154.39	456	476
7	1	9.64	—	0.14	346.66	667	687
8	1	9.70	—	0.13	462.23	672	693

C7814 - SS/950/TA-1
centroid adjustment : +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.11	—	0.14	2426.75	76	96
2	1	3.66	Ca	0.13	3687.99	197	217
3		3.97	Ca	0.14	436.96	222	241
4	1	9.66	—	0.06	260.22	669	690

(continued)

C7514 - SS/950/TA-2
centroid adjustment +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.45	Al	0.04	151.51	28	40
2	1	2.12	—	0.15	2510.00	76	96
3	1	3.65	Ca	0.13	2995.71	197	217
4		3.98	Ca	0.14	444.49	223	242
5	1	9.67	—	0.10	466.50	670	691

C7514 - SS/1050/TA-3
centroid adjustment : +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.11	—	0.13	2666.00	75	96
2	1	3.65	Ca	0.13	3993.72	197	217
3		3.97	Ca	0.14	466.46	223	242
4	1	9.64	—	0.11	362.50	667	686

C7514 - SS/1760/SP-4
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.41	Al	0.11	71.86	23	43
2	1	1.70	Si	-0.02	377.55	43	64
3	1	2.12	—	0.15	2019.74	76	97
4	1	3.65	Ca	0.13	4457.36	197	217
5	1	3.96	Ca	0.12	670.98	223	243
6	1	9.65	—	0.13	354.47	666	669

C7514 - SS/1760/SP 5
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.43	Al	0.09	896.55	22	43
2	1	1.70	Si	0.12	6169.99	44	64
3	1	2.12	—	0.16	1452.72	76	97
4	1	3.29	K	0.05	132.96	168	186
5	1	3.66	Ca	0.10	406.99	197	218
6	1	9.62	—	0.06	152.66	664	684
7	1	9.65	—	0.09	282.78	667	686
8	1	9.68	—	0.02	210.25	671	692

C7514 - SS/1760/SP-6
centroid adjustment : +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.40	Al	0.01	21.00	27	39
2	1	2.11	—	0.15	2658.13	76	96
3	1	3.65	Ca	0.13	5497.99	197	217
4	1	3.98	Ca	0.14	656.09	223	243
5	1	9.67	—	0.14	230.22	670	691

C7514 - SS/1760/SP-7
centroid adjustment : +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.70	Si	0.12	1619.23	43	64
2	1	2.11	—	0.15	2373.46	76	96
3	1	3.65	Ca	0.12	2430.25	197	217
4	1	5.66	Mn	0.12	696.63	370	390
5	1	6.36	Fe	0.13	876.56	410	430
6	1	6.87	Fe	0.07	17.04	460	480
7	1	9.64	—	0.15	366.26	666	667

C7514 - SS/1760/SP-8
centroid adjustment : +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.11	—	0.13	2111.79	75	96
2	1	3.65	Ca	0.13	4998.65	197	217
3		3.96	Ca	0.11	553.96	222	243
4	1	6.37	Fe	0.11	155.45	411	432
5	1	6.40	Fe	0.13	194.60	414	434
6	1	9.67	—	0.11	329.61	670	690

C7514 - SS/880/SP-9
centroid adjustment : +0.05

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.01	-114.71	25	45
2	1	2.11	—	0.13	1512.00	75	96
3	1	3.65	Ca	0.11	533.56	197	217
4	1	6.36	Fe	0.15	6461.20	409	430
5	1	7.01	Fe	0.13	936.97	460	481
6	1	9.67	—	-0.01	104.11	669	669

(continued)

C7S14 - SS/440/SP-10

centroid adjustment : +0 08

```
NC. ECL     CENTROID        FWHM      AREA     LEFT RIGHT

 1   1        2.11  —       0.14     2435.53    75    96
 2   1        3.65  Ca      0.13     3415.36   197   217
 3            3.98  Ca      0.11      391.83   224   248
 4   1        9.66  —       0.11      358.00   668   689
```

C8S15 - SS/550/TA-1

centroid adjustment +0 04

```
NC. ECL     CENTROID        FWHM      AREA     LEFT RIGHT

 1   1        2.12  —       0.14     2716.96    76    97
 2   1        3.66  Ca      0.12     2741.46   197   217
 3   1        3.96  Ca      0.13      389.36   223   243
 4   1        9.65  —       0.06      266.27   668   686
```

C8S15 - SS/1050/TA-2

Centroid adjustment : +0 05

```
NC. ECL     CENTROID        FWHM      AREA     LEFT RIGHT

 1   1        2.11  —       0.14     3084.74    75    96
 2   1        3.65  Ca      0.13     3181.85   197   217
 3   1        3.99  Ca      0.11      593.10   224   244
 4   1        9.65  —       0.09      369.00   668   689
```

C8S15 - SS/1100/TA-3

centroid adjustment +0 05

```
NC. ECL     CENTROID        FWHM      AREA     LEFT RIGHT

 1   1        2.11  —       0.15     2861.20    75    96
 2   1        3.65  Ca      0.13     3476.60   197   217
 3   1        3.96  Ca      0.13      506.83   223   243
 4   1        9.67  —       0.13      267.73   670   691
```

C8S15 - SS/450/SP-4

centroid adjustment +0 04

```
NC. ECL     CENTROID        FWHM      AREA     LEFT RIGHT

 1   1        2.12  —       0.16     2409.02    76    97
 2   1        2.60  Cl      0.07      113.70   112   133
 3   1        3.66  Ca      0.12     1497.72   197   216
 4   1        9.66  —       0.14      455.53   668   689
 5   1        9.72  —       0.10      311.74   675   695
```

C8S16 - SS/450/SP-5

Centroid adjustment : +0 04

```
NC. ECL     CENTROID        FWHM      AREA     LEFT RIGHT

 1   1        2.12  —       0.16     2552.75    76    97
 2   1        3.66  Ca      0.14     2916.70   197   216
 3   1        4.00  Ca      0.09      166.63   226   246
 4   1        9.65  —       0.10      169.03   667   668
 5   1        9.69  —       0.05      402.00   672   692
```

C8S16 - SS/825/TA-1

Centroid adjustment . +0 04

```
NC. ECL     CENTROID        FWHM      AREA     LEFT RIGHT

 1   1        1.43  Al      0.07      143.50    22    42
 2   1        1.70  Si      0.10     1277.00    43    64
 3   1        2.12  —       0.17     2461.97    76    97
 4   1        3.65  Ca      0.13     1962.24   197   217
 5            3.96  Ca      0.08      155.24   226   240
 6   1        6.36  Fe      0.13     1196.49   410   430
 7   1        9.65  —       0.15      362.00   666   689
```

C8S16 - SS/1150/TA-2

Centroid adjustment : +0 05

```
NC. ECL     CENTROID        FWHM      AREA     LEFT RIGHT

 1   1        1.49  Al     -0.02      -22.48    21    42
 2   1        1.70  Si      0.11     1901.97    43    64
 3   1        2.11  —       0.13     2909.74    76    96
 4   1        3.64  Ca      0.14     3030.56   196   216
 5   1        3.97  Ca      0.07      352.23   223   243
 6   1        6.35  Fe      0.16     1444.13   409   429
 7   1        6.98  Fe      0.08      220.54   457   477
 6   1        9.65  —       0.15      367.66   666   686
```

C8S16 - SS/2100/TA-3

Centroid adjustment : +0 05

```
NO. ECL     CENTROID        FWHM      AREA     LEFT RIGHT

 1   1        1.70  Si      0.12     2223.70    43    64
 2   1        2.11  —       0.12     1642.24    76    96
 3   1        3.65  Ca      0.13     2743.24   197   217
 4   1        3.98  Ca      0.14      329.71   223   243
 5   1        6.36  Fe      0.14     1466.23   410   430
 6   1        6.99  Fe      0.09      144.56   461   481
 7   1        9.66  —       0.10      179.45   670   691
```

(continued)

CB516 - SS/460/SP-4

centroid adjustment : + 0 04

NC. FCL		CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.71	Si	0.08	432.77	44	65
2	1	2.12	—	0.18	2270.23	76	97
3	1	3.66	Ca	0.13	5301.63	197	217
4		3.97	Ca	0.10	618.00	282	242
5	1	6.35	Fe	0.10	56.09	409	429
6	1	9.60	—	0.08	140.90	664	664

CB516 - SS/460/SP-5

centroid adjustment , +0 05

NC. ECL		CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.70	Si	0.11	5779.28	43	64
2	1	2.11	—	0.15	2805.48	75	96
3	1	3.65	Ca	0.08	574.71	197	217
4	1	6.36	Fe	0.09	487.74	409	430
5	1	9.67	—	0.13	266.10	670	690

CB516 - SS/460/SP-6

centroid adjustment : +0.06

NC. ECL		CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.42	Al	0.03	71,03	25	40
2	1	1.70	Si	0.18	3093.46	43	64
3	1	2.10	—	0.14	2585.72	75	95
4	1	3.65	Ca	0.13	2869.60	197	217
5	1	6.35	Fe	0.14	1337.63	409	429
6	1	9.65	—	0.09	387.70	668	689

CB516 - SS/1850/SP-7

centroid adjustment : +0 05

NC. FCL		CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.19	Mg	0.14	367.50	4	25
2		1.42	Al	0.10	836.77	25	39
3	1	1.69	Si	0.12	1561.22	43	64
4	1	2.11	—	0.14	3077.49	75	96
5	1	3.65	Ca	0.12	3069.98	197	217
6		3.97	Ca	0.13	469.75	222	242
7	1	6.36	Fe	0.12	322.08	410	430
8	1	9.66	—	0.06	253.99	668	668
9	1	9.69	-	0.03	277.98	673	694

CB816 - SS/460/SP-7

centroid adjustment , +0 05

NC. ECL		CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.11	—	0.16	2876.83	76	96
2	1	3.65	Ca	0.18	4913.06	197	217
3		3.97	Ca	0.13	592.74	223	241
4	1	6.36	Fe	0.17	213.74	409	430
5	1	9.65	—	0.10	346.01	668	669

CB516 - SS/460/SP-8

centroid adjustment . +0 05

NC. ECL		CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.69	Si	0.13	1069.76	43	63
2	1	2.11	—	0.16	2528.98	76	96
3	1	3.65	Ca	0.14	4432.61	197	217
4	1	3.97	Ca	0.12	423.23	222	242
5	1	6.36	Fe	0.11	492.09	410	430
6		7.01	Fe	0.02	29.67	465	479
7	1	9.66	—	0.03	354.10	671	691

C9517 - SS/1140/AR-1

centroid adjustment . +0 03

NO. ECL		CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.69	Si	0.08	350.92	57	77
2	1	2.13	—	0.15	7500.47	90	110
3	1	3.66	Ca	0.15	1322.03	204	225
4	1	6.38	Fe	0.17	1787.24	408	428
5	1	9.66	—	0.16	1704.83	653	673
6	1	11.36	—	0.09	422.02	779	800

C9517 - SS/1140/AR-2

centroid adjustment : +0 03

NO. ECL		CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.09	475.25	39	60
2	1	2.13	—	0.16	1337.99	89	110
3	1	3.67	Ca	0.15	2844.99	205	225
4	1	6.37	Fe	0.14	3264.64	407	427
5	1	7.02	Fe	0.03	366.59	456	476
6	1	9.66	—	0.13	1903.83	653	673
7	1	11.42	—	0.16	755.59	785	805

(continued)

c9517 - ss/1140/sp-3
centroid adjustment : + 0.02

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.10	406.66	40	60
2	1	2.14	—	0.17	1475.50	90	110
3		3.68	Ca	0.08	234.30	204	225
4		5.92	Cr	0.06	41.75	371	391
5	1	6.38	Fe	0.16	7088.22	407	428
6	1	7.04	Fe	0.12	1010.48	457	477
7	1	9.66	—	0.12	503.47	653	674
8	1	11.41	—	0.16	218.78	783	804

c9517 - ss/1140/sp-4
centroid adjustment : +0 02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.45	Al	0.08	20.38	47	51
2	1	2.13	—	0.16	3293.74	89	110
3	1	3.67	Ca	0.14	2803.24	205	225
4		3.99	Ca	0.11	379.74	230	247
5		5.39	—	0.11	266.50	338	349
6	1	5.86	Cr	0.15	1252.48	369	389
7	1	6.37	Fe	0.15	6923.11	407	427
8	1	7.04	Fe	0.14	819.20	456	477
9	1	9.65	—	0.16	726.39	652	672
10		9.70	—	54.73	-24.63	665	669
11		11.33	—	0.08	151.63	783	793

c9518 - ss/620/TA-1
centroid adjustment : -0 02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.76	Si	0.12	578.54	48	68
2	1	2.16	—	0.16	4335.46	61	102
3	1	3.72	Ca	0.09	443.46	201	222
4	1	6.44	Fe	0.06	233.75	416	436
5	1	9.72	—	0.10	433.00	673	694

c9518 - ss/625/TA-2
centroid adjustment : -0 02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	2.16	—	0.14	4216.70	81	102
2	1	5.93	Cr	0.13	926.73	375	396
3	1	6.43	Fe	0.14	1565.36	415	435
4	1	7.07	Fe	0.08	144.70	465	486
5	1	9.72	—	0.10	634.23	673	694

c9518 - ss/625/TA-3
centroid adjustment : -0 03

NC.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.71	Si	0.03	64.63	47	59
2	1	2.19	—	0.16	3165.64	68	102
3	1	3.72	Ca	0.12	1351.45	202	223
4	1	4.05	Ca	0.11	69.75	229	250
5	1	9.72	—	0.12	602.01	673	694

c9518 - ss/1100/sp-4
centroid adjustment : -0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.51	Al	0.04	109.35	29	49
2	1	2.16	—	0.03	117.30	60	101
3	1	3.72	Ca	0.10	531.46	202	223
4	1	6.43	Fe	0.13	345.20	415	436
5	1	9.71	—	0.10	753.41	673	693
6	1	13.31	—	0.05	47.29	957	977

c9518 - ss/1100/sp-5
centroid adjustment : -0 02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.74	Si	0.14	436.76	46	66
2	1	2.18	—	0.15	4473.46	61	101
3	1	3.72	Ca	0.10	944.97	202	222
4	1	6.43	Fe	0.09	139.50	415	435
5	1	9.73	—	0.14	437.71	674	695
6	1	11.59	—	-0.56	32.24	819	839

c10519 - BFS/600/sp-1
centroid adjustment : +0 04

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1		1.70	0.12	940.75	56	77
2	1	2.12	0.17	2458.72	67	106
3	1	6.37	0.16	6268.25	404	424
4	1	7.08	0.14	501.29	451	472
5	1	9.66	0.14	1663.22	649	669

c10519 - BFS/1200/sp-2
centroid adjustment : +0 03

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	2.13	0.13	927.46	86	106
2	1	6.38	0.17	5096.00	404	425
3	1	9.67	0.11	936.50	650	670

(continued)

C10819 - BFS/1200/SP-3
centroid adjustment +0 04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.41	Al	0.10	199.30	37	58
2	1	2.12	—	0.15	840.60	87	107
3	1	6.37	Fe	0.14	7876.23	404	424
4	1	7.04	Fe	0.08	829.28	453	474
5	1	9.65	—	0.14	2364.99	648	669

C10819 - BFS/1200/SP-4
centroid adjustment : +0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.04	425.14	39	59
2	1	2.14	—	0.16	1429.75	88	109
3	1	6.39	Fe	0.16	6065.47	405	425
4	1	7.08	Fe	0.13	638.67	452	472
5	1	9.66	—	0.14	869.74	649	670

C10819 - BFS/1200/SP-5
centroid adjustment : +0.05

NO.	ECL	CENTROID	FWHM	AREA	LEFT	RIGHT
1	1	1.44	0.11	444.05	36	57
2	1	2.11	0.10	1119.70	86	107
3	1	6.37	0.15	8365.61	404	424
4	1	7.03	0.17	1326.84	453	473
5	1	9.66	0.16	2052.83	649	669

C10819 - BFS/2400/SP-6
centroid adjustment +0 04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.69	Si	0.13	1983.71	55	75
2	1	2.12	—	0.16	11683.97	87	107
3	1	3.65	Ca	0.17	910.74	201	222
4	1	6.37	Fe	0.14	2867.60	404	424
5	1	9.65	—	0.16	1512.71	648	669

C10819 - BFS/2400/SP-7
centroid adjustment +0 04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.71	Si	0.12	12891.46	56	77
2	1	2.12	—	0.15	8071.25	87	107
3	1	6.37	Fe	0.14	2764.06	404	424
4	1	9.65	—	0.16	1258.00	646	669

C10819 - BFS/2400/SP-8
centroid adjustment : +0 03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.46	Al	0.12	1099.75	38	58
2	1	2.13	—	0.17	1144.20	87	108
3	1	6.38	Fe	0.16	5459.20	404	425
4	1	7.03	Fe	0.13	764.25	453	474
5	1	9.66	—	0.18	2499.74	649	670
6	1	11.38	—	0.09	645.13	777	797

C10819 - BFS/2400/SP-9
centroid adjustment : +0.04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.69	Si	0.15	1304.04	56	75
2	1	2.12	—	0.15	2282.00	87	107
3	1	3.66	Ca	0.14	1577.72	202	223
4	1	6.37	Fe	0.14	2721.86	404	424
5	1	9.66	—	0.15	1581.99	649	669

C10819 - BFS/2400/SP-10
centroid adjustment : +0 04

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.70	Si	0.13	1811.29	55	76
2	1	2.12	—	0.16	10192.75	87	107
3	1	3.67	Ca	0.16	988.70	202	223
4	1	6.37	Fe	0.15	2679.08	404	424
5	1	9.66	—	0.15	1443.23	649	670

(continued)

C10S20 - BFS/1100/TA-1
centroid adjustment - 0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.51	Al	0.10	291.71	26	49
2	1	2.18	—	0.11	616.29	81	101
3	1	3.72	Ca	0.06	103.35	202	222
4	1	9.72	—	0.14	1122.97	673	694
5	1	13.35	—	0.01	122.74	956	976
6	1	13.37	—	0.01	121.13	961	961

C10S20 - BFS/1100/SP-2
centroid adjustment : -0.02

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.48	Al	0.07	116.08	28	49
2	1	1.76	Si	0.09	901.88	48	68
3	1	2.18	—	0.14	1548.47	81	101
4	1	3.70	Ca	0.10	210.53	200	221
5	1	6.35	—	0.10	-5.77	578	598
6	1	9.72	—	0.16	1145.97	673	694
7		11.47	—	0.03	31.13	816	824

C10S20 - BFS/1100/SP-3
centroid adjustment : -0.03

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.52	Al	0.11	398.29	30	51
2	1	2.20	—	0.12	253.25	63	103
3	1	3.72	Ca	0.07	149.70	202	223
4	1	4.07	Ca	0.02	27.70	229	250
5	1	6.41	Fe	0.09	835.01	414	434
6	1	6.53	—	~~0.02~~	118.30	560	601
7	1	9.72	—	0.17	1248.97	673	694
8	1	11.47	—	0.13	342.76	811	831

C10S20 - BFS/1100/SP-4
centroid adjustment : -0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.07	866.91	28	48
2	1	2.17	—	0.09	210.74	61	101
3	1	3.71	Ca	0.11	1726.20	201	222
4	1	9.71	—	0.10	1023.24	673	693
5	1	11.49	—	0.03	367.99	811	832

C10S20 - BFS/1100/SP-5
centroid adjustment - 0.01

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.47	Al	0.04	139.66	27	47
2	1	2.17	—	0.16	3623.70	60	101
3	1	3.71	Ca	0.07	123.75	203	223
4	1	6.37	Fe	0.12	72.30	413	434
5	1	9.72	—	0.14	972.22	673	694

CHS21 - BFS/1300/TA-1
centroid adjustment : +0.14

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.60	Si	0.13	1091.66	36	56
2	1	2.08	—	0.14	2960.95	66	89
3	1	3.55	Ca	0.14	595.13	169	209
4	1	9.56	—	0.16	670.11	661	681
5	1	11.31	—	0.04	306.01	796	816

CHS21 - BFS/1300/AR-2
centroid adjustment : +0.14

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.33	Al	0.06	222.54	17	37
2	1	1.60	Si	0.13	2315.20	36	57
3	1	2.02	—	0.15	2621.49	66	89
4	1	3.56	Ca	0.14	1713.46	189	210
5	1	6.26	Fe	0.14	716.34	402	422
6		6.90	Fe	0.02	134.00	455	469
7	1	9.57	—	0.18	336.09	661	682
8	1	11.31	—	0.04	153.51	797	817

CHS21 - BFS/1300/AR-3
centroid adjustment . +0.15

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.34	Al	0.07	141.00	20	31
2	1	1.59	Si	0.11	2501.72	35	56
3	1	2.01	—	0.15	2150.49	67	88
4	1	3.55	Ca	0.13	3469.49	169	209
5	1	3.68	Ca	0.10	493.21	215	235
6	1	9.55	—	0.04	253.00	660	660

(continued

CHS21 - BPS/690/SP-4
centroid adjustment +0.12

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.37	Al	0.03	45.78	17	36
2	1	1.64	Si	0.06	171.98	38	59
3	1	2.04	–	0.11	274.70	70	91
4	1	3.58	Ca	0.13	1366.50	191	211
5	1	3.90	Ca	0.05	308.21	216	237
6	1	9.58	–	0.15	1252.49	662	683

CHS21 - BPS/690/SP-5
centroid adjustment : +0.12

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.36	Al	0.12	114.65	17	37
2	1	1.62	Si	0.08	65.29	37	57
3	1	2.04	–	0.06	214.74	70	91
4	1	3.58	Ca	0.13	1968.00	191	211
5	1	3.89	Ca	0.16	379.74	216	236
6	1	9.58	–	0.14	632.99	662	683

CHS21 - BPS/1300/SP-6
centroid adjustment : +0.15

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.59	Si	0.11	1710.60	35	55
2	1	2.01	–	0.12	2330.08	68	66
3	1	2.48	Cl	0.09	1017.09	105	125
4		3.17	K	51.48	-31.00	167	171
5	1	3.54	Ca	0.13	1594.24	166	209
6	1	3.66	Ca	0.12	243.47	212	233
7	1	9.57	–	0.09	329.59	641	661
8		11.36	–	0.06	65.49	606	823

CHS21 - BPS/1300/SP-7
centroid adjustment : +0.14

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.60	Si	0.12	1633.23	35	56
2	1	2.02	–	0.14	927.49	68	89
3	1	3.55	Ca	0.13	3606.10	189	209
4	1	3.86	Ca	0.06	447.97	214	235
5	1	5.77	Mn	0.01	112.66	363	363
6	1	6.26	Fe	0.14	173.70	401	422
7	1	9.55	–	0.07	266.66	659	679

CHS21 - BPS/1400/SP-8
centroid adjustment +0.13

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.37	Al	0.07	536.01	20	35
2	1	1.63	Si	0.12	3924.66	36	56
3	1	2.03	–	0.15	1635.74	70	90
4	1	3.56	Ca	0.13	4199.66	191	211
5	1	3.91	Ca	0.13	399.71	217	237
6	1	9.60	–	0.14	273.00	664	684
7	1	11.32	–	0.07	90.17	799	819

CHS21 - BPS/1400/SP-9
centroid adjustment : +0.11

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.39	Al	0.11	469.23	19	39
2	1	3.57	Ca	-0.01	26.46	194	214
3	1	9.60	–	0.16	660.72	664	685
4	1	11.33	–	0.06	267.51	799	619

CHS21 - BPS/1400/SP-10
centroid adjustment : +0.12

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.22	–	0.06	67.53	16	39
2	1	1.63	Si	0.12	3015.99	38	59
3	1	2.04	–	0.16	2422.96	70	91
4	1	3.56	Ca	0.12	2876.24	191	212
5	1	3.91	Ca	0.07	352.66	216	236
6	1	9.56	–	0.16	359.14	662	662

CHS21 - BPS/1400/SP-11
centroid adjustment : +0.11

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.37	Al	0.12	213.55	16	39
2	1	1.63	Si	0.09	244.46	36	59
3	1	2.05	–	0.15	341.47	70	91
4	1	3.56	Ca	0.12	317.77	191	212
5	1	9.59	–	0.17	1025.50	663	664
6	1	11.31	–	0.14	349.50	797	616

(continued)

CHS21 - BFS/2600/SP-12

Centroid adjustment + 0 16

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.56	Si	0.11	1617.53	34	55
2	1	2.00	—	0.16	2770.50	67	87
3	1	3.54	Ca	0.13	2386.98	186	206
4	1	3.66	Ca	0.18	525.71	213	233
5	1	9.56	—	0.10	430.74	660	681

CHS22 - BFS/250/AR-1

Centroid adjustment : + 0 22

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.53	Si	0.10	3103.00	30	51
2	1	1.94	—	0.14	1943.49	62	63
3	1	3.48	Ca	0.14	3316.60	183	203
4	1	3.79	Ca	0.15	476.63	206	226
5	1	9.50	—	0.12	804.82	656	677

CHS22 - BFS/650/AR-2

Centroid adjustment : +0.20

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.55	Si	0.12	3779.73	32	52
2	1	1.96	—	0.15	1764.11	64	84
3	1	3.50	Ca	0.12	3410.10	185	205
4	1	3.82	Ca	0.13	518.88	210	230
5	1	9.52	—	0.16	318.85	656	678

CHS22 - BFS/250/SP-3

Centroid adjustment : + 0 22

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.53	Si	0.03	99.42	31	51
2	1	1.94	—	0.13	597.99	62	83
3		2.76	—	0.10	2032.03	127	148
4	1	2.97	—	0.11	456.88	143	163

CHS22 - BFS/250/SP-4

Centroid adjustment + 0 24

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.51	Si	0.12	564.96	26	46
2	1	1.92	—	0.15	1604.71	60	81
3	1	2.75	—	0.12	2226.51	126	147
4	1	2.94	—	51.73	-977.01	141	162
5		9.52	—	0.14	267.97	660	677

CHS22 - BFS/250/SP-5

Centroid adjustment + 0 29

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.46	Si	0.12	271.46	25	44
2	1	1.87	—	0.11	796.66	57	77
3	1	2.71	—	0.11	2779.79	123	143
4		2.90	—	0.09	444.24	142	156
5		9.39	—	0.05	93.00	652	663
6	1	9.43	—	0.06	118.66	650	670

CHS22 - BFS/650/SP-6

Centroid adjustment : +0 20

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.54	Si	0.13	756.24	31	51
2	1	1.96	—	0.16	3035.22	63	84
3		2.44	Cl	51.72	-33.00	109	113
4	1	2.77	—	0.10	1532.30	126	149
5	1	2.95	—	0.02	-377.76	143	163
6	1	3.51	Ca	0.10	464.06	165	205
7		9.46	—	0.06	141.49	659	671

CHS22 - BFS/650/SP-7

Centroid adjustment . +0 20

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1		1.51	Si	0.04	34.00	37	41
2	1	1.55	Si	0.06	300.99	32	52
3	1	1.96	—	0.13	2149.22	64	64
4	1	2.79	—	0.12	1744.04	129	150
5		2.99	—	0.04	64.66	150	162
6	1	3.47	Ca	0.06	69.97	166	206
7	1	9.46	—	0.14	292.00	655	675

(continued)

C12524 - BFS/460/SP-1
Centroid adjustment : +0.0

NO.	FCL	CENTROID		FWHM	ARFA	LEFT	RICHT
1	1	1.49	Al	0.07	570.91	39	59
2		1.74	Si	0.12	550.85	58	76
3	1	2.16	–	0.15	3030.46	88	109
4	1	3.69	Ca	0.15	1807.47	203	224
5	1	6.39	Fe	0.16	1703.74	405	426
6	1	7.08	Fe	0.14	487.04	453	473
7	1	9.66	–	0.16	2667.73	650	671
8	1	11.48	–	0.10	948.16	782	802

C12524 - BFS/920/SP-2
Centroid adjustment +0 0

NC.	FCL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.50	Al	0.09	699.16	39	59
2	1	2.16	–	0.11	692.61	89	109
3	1	3.70	Ca	0.13	1855.23	203	224
4	1	4.01	Ca	0.10	430.50	227	247
5	1	6.40	Fe	0.16	648.00	406	426
6	1	9.68	–	0.15	2501.13	652	672
7	1	11.41	–	0.15	750.01	781	802

C12524 - BFS/1830/SP-3
Centroid adjustment : +0 0

NC.	ECL	CFNTROID		FWHM	AREA	LEFT	RIGHT
1		1.49	Al	0.10	1391.88	39	59
2		1.76	Si	0.08	190.11	63	75
3	1	2.17	–	0.16	1488.22	89	109
4	1	3.70	Ca	0.17	600.61	204	224
5	1	6.40	Fe	0.15	11738.13	406	426
6	1	7.05	Fe	0.15	1577.38	455	475
7	1	9.68	–	0.14	2879.38	652	672
8	1	11.42	–	0.12	687.28	782	802

C12524 - BFS/1820/SP-4
Centroid adjustment : +0 0

NO.	ECL	CENTROID		FWHM	AREA	LEFT	RIGHT
1	1	1.48	Al	0.11	696.79	38	59
2	1	1.75	Si	0.07	330.79	56	76
3	1	2.16	–	0.15	3144.73	89	109
4	1	3.70	Ca	0.12	806.63	204	224
5	1	4.00	Ca	0.08	295.70	226	247
6	1	6.39	Fe	0.06	477.01	404	425
7	1	9.68	–	0.16	4317.22	651	672
6	1	11.39	–	0.13	1128.67	780	800

APPENDIX F :

PSV READINGS FOR LONG TERM WEATHERING STUDY

The results of long-term weathering study are given in Table F-1.

Table F-1 PSV Readings for Long-term
Weathering Study

a. TYPE OF AGGREGATE : Traprock

TYPE OF SOLUTION	No. of days immersed in the solution								
	0	1	3	6	10	15	21	28	42
Distilled water	45	48	47	47	48	48	50	50	50
Rainfall water	45	47	46	46	47	47	49	49	49
Synthetic rainwater	45	48	47	47	48	48	48	48	48
1% by wt. $CaCl_2$ solution	45	46	46	48	47	47	47	48	48

b. TYPE OF AGGREGATE : Limestone (Canada Crush)

TYPE OF SOLUTION	No. of days immersed in the solution								
	0	1	3	6	10	15	21	28	42
Distilled water	43	49	49	51	53	55	57	58	60
Rainfall water	43	65	66	67	70	74	80	87	89
Synthetic rainwater	42	66	67	76	82	83	85	89	90
1% by wt. $CaCl_2$ solution	43	45	46	47	44	45	45	47	48

(continued)

c. TYPE OF AGGREGATE : Dofasco Steel Slag

TYPE OF SOLUTION	No. of days immersed in the solution								
	0	1	3	6	10	15	21	28	42
Distilled water	49	51	54	55	56	58	60	62	65
Rainfall water	51	56	53	54	54	54	55	54	53
Synthetic rainwater	49	54	54	61	63	65	67	70	72
1% by wt. $CaCl_2$ solution	45	46	46	48	46	47	46	48	48

d. TYPE OF AGGREGATE : Blast Furnace Slag

TYPE OF SOLUTION	No. of days immersed in the solution								
	0	1	3	6	10	15	21	28	42
Distilled water	54	55	55	56	57	60	61	61	62
Rainfall water	53	55	54	54	54	54	55	56	56
Synthetic rainwater	55	67	75	78	79	81	81	81	81
1% by wt. $CaCl_2$ solution	55	58	57	56	58	58	57	58	58

APPENDIX G :

PSV READINGS FOR CYCLIC WEATHERING STUDY

The results of the first phase of cyclic weathering are given in Table G-1; and the second phase of cyclic weathering are given in Table G-2.

Table G-1. PSV Readings for Cyclic Weathering - Phase 1

a. TYPE OF AGGREGATE : Traprock

TYPE OF SOLUTION	CYCLE					
	wet	dry	wet	dry	wet	
	No. of DAYS					
	0	1	2	3	4	5
Distilled water	47	49	49	49	49	49
Rainfall water	49	50	50	51	51	51
Synthetic rainwater	47	48	48	49	49	49
1% by wt. $CaCl_2$ solution	48	47	48	48	49	48

b. TYPE OF AGGREGATE : Limestone (Canada Crush)

TYPE OF SOLUTION	CYCLE					
	wet	dry	wet	dry	wet	
	No. of DAYS					
	0	1	2	3	4	5
Distilled water	51	55	55	55	56	58
Rainfall water	46	69	70	80	80	84
Synthetic rainwater	53	71	73	79	80	84
1% by wt. $CaCl_2$ solution	48	49	50	48	51	47

(continued)

c. TYPE OF AGGREGATE : Dofasco Steel Slag

TYPE OF SOLUTION	CYCLE					
	wet	dry	wet	dry	wet	
	No. of DAYS					
	0	1	2	3	4	5
Distilled water	54	58	58	63	62	63
Rainfall water	52	54	54	53	53	53
Synthetic rainwater	55	68	70	70	69	71
1% by wt. $CaCl_2$ solution	49	48	47	46	49	45

d. TYPE OF AGGREGATE : Blast Furnace Slag

TYPE OF SOLUTION	CYCLE					
	wet	dry	wet	dry	wet	
	No. of DAYS					
	0	1	2	3	4	5
Distilled water	55	55	55	55	55	55
Rainfall water	54	55	55	55	55	55
Synthetic rainwater	59	69	70	72	72	77
1% by wt. $CaCl_2$ solution	55	57	57	57	57	57

Table G-2. PSV Readings for Cyclic Weathering - Phase 2

a. TYPE OF AGGREGATE : Traprock

TYPE OF SOLUTION	CYCLE							
	wet	dry	wet	dry	wet	dry	wet	
	No. of DAYS							
	0	1	3	4	6	7	9	10
Distilled water	47	50	50	50	50	50	50	51
Rainfall water	48	48	49	49	50	50	49	49
Synthetic rain	47	49	49	50	50	50	50	51
1% by wt. $CaCl_2$ solution	47	47	48	48	48	48	49	49

b. TYPE OF AGGREGATE : Limestone (Canada Crush)

TYPE OF SOLUTION	CYCLE							
	wet	dry	wet	dry	wet	dry	wet	
	No. Of DAYS							
	0	1	3	4	6	7	9	10
Distilled water	52	56	56	57	57	57	56	57
Rainfall water	48	70	72	81	82	86	88	89
Synthetic rain	53	71	71	81	81	88	88	89
1% by wt. $CaCl_2$ solution	46	49	49	50	50	50	50	50

(continued)

c. TYPE OF AGGREGATE : Dofasco Steel Slag

TYPE OF SOLUTION	CYCLE							
	wet	dry	wet	dry	wet	dry	wet	
	No. of DAYS							
	0	1	3	4	6	7	9	10
Distilled water	59	63	63	64	64	65	65	65
Rainfall water	51	53	51	51	51	53	53	53
Synthetic rain	56	67	67	69	69	70	70	71
1% by wt. $CaCl_2$ solution	47	48	48	48	48	48	49	49

d. TYPE OF AGGREGATE : Blast Furnace Slag

TYPE OF SOLUTION	CYCLE							
	wet	dry	wet	dry	wet	dry	wet	
	No. of DAYS							
	0	1	3	4	6	7	9	10
Distilled water	55	55	55	56	56	56	56	56
Rainfall water	54	54	54	54	54	55	55	55
Synthetic rain	57	68	68	74	75	79	80	82
1% by wt. $CaCl_2$ solution	56	56	56	57	57	57	57	57

APPENDIX H :

PSV READINGS FOR SPECIAL STUDIES ON WEATHERING

The results of long-term weathering in 1% by weight NaCl solution are given in Table H-1. The second part of the special studies is the short-term weathering. The results of this study are given in Table H-2.

Table H-1. Long-term Weathering in 1% by Weight NaCl Solution

TYPE OF SOLUTION : 1% by-weight NaCl solution

TYPE OF AGGREGATE	No. of days immersed in the solution								
	0	1	3	6	10	15	21	28	42
Traprock	46	50	52	51	52	52	52	52	52
Limestone (Canada Crush)	49	52	55	56	57	57	57	57	57
Dofasco Steel Slag	46	50	54	54	54	54	54	54	54
Blast Furnace Slag	53	56	57	57	57	57	57	57	57

TABLE H-2. PSV Readings on Short-term Weathering

a. TYPE OF SOLUTION : Synthetic rainwater

TYPE OF AGGREGATE	No. of HOURS immersed in the solution									
	0	2	4	6	9	12	16	23	29	42
Limestone (Canada Crush)	44	65	70	71	83	85	85	85	88	90
Dofasco Steel Slag	52	56	59	58	60	60	60	61	63	67
Blast Furnace Slag	56	74	78	74	78	78	79	78	81	81

b. TYPE OF SOLUTION : Distilled water

TYPE OF AGGREGATE	No. of HOURS immersed in the solution						
	0	1.5	4.5	7.5	20	27	42
Limestone (Canada Crush)	46	50	50	51	53	54	54
Dofasco Steel Slag	52	53	55	57	59	60	60
Blast Furnace Slag	56	57	57	57	57	57	57

APPENDIX I :

WEATHERING EFFECTS ON SKID RESISTANCE : CHEMICAL ANALYSIS

I.1 PURPOSE

The purpose of the chemical analyses was to obtain information regarding the changes of PSV of the aggregates under various weathering conditions.

I.2 METHODS

To monitor any chemical reactions which occurred when the aggregates were subjected to simulated weathering, a Hach Direct Reading Kit, Model DR-EL/2 was used and pH readings were taken using a laboratory pH meter.

I.3 SAMPLING PROCEDURE

There were a total of 20 samples (4 different aggregates subjected to 5 different solutions). These aggregates were traprock, limestone (Canada Crush), blast furnace slag and Dofasco steel slag. The solutions were distilled water, synthetic rainwater, rainfall water (Hamilton, May 24th, 1979), 1% by weight $CaCl_2$ solution and 1% by weight NaCl solution.

Each of the samples contained about 150 g of aggregate and about 200 ml of solution. Since this test was conducted to find the chemical analysis qualitatively, variations in weight of the sample will not affect the results. The aggregates were submerged in the solution for 2 days to obtain chemical quilibrium, as well as for any crystallization and/or leaching process to occur.

I.4 TYPE OF ANALYSIS

The types of analysis selected were as follows:

1. pH Readings : All readings were taken using a Sargent-Welch pH meter, model PBL.
2. Carbon dioxide (partial) : Check for the presence of dissolve CO_2 in the solutions.
3. Chloride : Mercuric Nitrate titration method.
4. Hardness, Mg and total : Used only to find total Hardness, Titration method - Man Ver® II
5. Iron, total : Used only for solutions from blast furnace slag and steel slag.
   1,10 phenanthroline method - Ferrover®

6. Nitrogen, Nitrate : Cadmium reduction method in Nitra Ver® V

7. Sulfate : Turbidimetric method - Sulfa Ver® IV

For analyses No. 2 to 7, the Hach Direct Reading Engineer's Laboratory Kit, Model DR-EL/2 was used. The procedure of these tests are described in section I.6 (25).

I.5 TEST RESULTS

1. pH Readings

The pH of the solutions are shown in Table I-1. Both the initial condition of the solutions and the pH after soaking the aggregates is given (pH 7 is normal, pH > 7.0 shows alkaline condition, while as pH < 7.0 shows that it is acidic). Generally, the results showed an increase of pH from the initial condition.

2. Dissolved CO_2

The purpose of this test is to show the presence of any CO_2 in the initial solutions. The results of these tests are given in Table I-2. Only qualitative measures of CO_2 are given since this is the important consideration.

Table I-1. pH Readings of the Solutions

		Readings after submersion of Aggregates :							
TYPE OF SOLUTION	INITIAL READING:	TRAP-ROCK		LIME-STONE		BLAST FURNACE SLAG		STEEL SLAG	
Distilled water	5.4	8.2	↑	7.8	↑	9.3	↑	12.5	↑
Synthetic rainwater	2.4	3.9	↑	6.8	↑	8.4	↑	12.4	↑
Rainfall water	4.5	8.6	↑	7.2	↑	9.3	↑	12.3	↑
1% by wt. $CaCl_2$ solution	6.0	8.0	↑	7.6	↑	8.9	↑	12.3	↑
1% by wt. NaCl solution	8.0	9.0	↑	8.2	↑	8.7	↑	12.1	↑

Note : ↑ pH increases

↓ pH decreases

Table I-2. The Presence of Dissolved CO_2 in the Solutions

TYPE OF SOLUTION	dissolved CO_2
Distilled water	+
Synthetic rainwater	+
Rainfall water	+
1 % by weight $CaCl_2$ sol.	+
1 % by weight NaCl sol.	+

\+ positive (present)

\- negative

Results from Table I-2 clearly show that distilled water obtained in the laboratory contains dissolved CO_2.

From the chemical reaction :

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \text{ (weak acid)},$$

the distilled water contains weak acid, hence its pH is lower than 7.0 as shown in Table I-2. The $CaCl_2$ and $NaCl_2$ were made from "distilled" water, therefore they also indicate the presence of weak acid H_2CO_3.

3. Concentrations of chloride $[Cl^-]$ in the solutions

The test results to determine the chloride $[Cl^-]$ in the solutions are given in Table I-3. Because of the very high concentration of chloride in the NaCl and $CaCl_2$ solutions (5000 mg/l), these solutions had to be diluted for analysis. Table I-3 shows that the concentration of chloride at the end of the chemical reactions depends on both the type of solution and the type of aggregate.

4. Hardness : Magnesium and Total

The results of this test, which was completed by a titration method, are given in Table I-4. Except for traprock in distilled water, the results indicate that the concentration of Magnesium (and total) in the solution increased after the end of the tests. For the case of traprock in distilled water, the final concentration is similar to its initial value. Due to the large concentration of Ca^{2+} in $CaCl_2$ solution, this solution had to be diluted for analysis.

5. Concentration of Iron Total in the solutions

The results of the test are given in Table I-5. Tests were not carried out for traprock and limestone aggregates. As shown in Table I-5, the concentration of iron total in the solutions increased after the soaking of steel slag and blast furnace slag.

Table I-3. The Concentrations of Chloride in the Solutions in mg/l

TYPE OF SOLUTION	INITIAL [CL⁻]	[CL⁻] after submersion of Aggregates :			
		TRAP-ROCK	LIME-STONE	BLAST FURNACE SLAG	STEEL SLAG
Distilled water	7.5	7.5	7.5	60.0 ↑	10.0 ↑
Synthetic rainwater	100.0	92.5 ↓	95.0 ↓	150.0 ↑	25.0 ↓
Rainfall water	7.5	12.5 ↑	10.0 ↑	70.0 ↑	17.5 ↑
1% by wt. $CaCl_2$ solution	7375	6250 ↓	8250 ↑	7500 ↑	7625 ↑
1% by wt. NaCL solution	6750	6250 ↓	6000 ↓	5750 ↓	7250 ↑

Note: ↑ [CL⁻] increases

↓ [CL⁻] decreases

Table I-4. The Concentrations of Magnesium and Total in the Solutions in mg/l

		[Total hardness] after submersion of Aggregates :			
TYPE OF SOLUTION	INITIAL [Mg^{2+}, Ca^{2+}]	TRAP-ROCK	LIME-STONE	BLAST FURNACE SLAG	STEEL SLAG
Distilled water	30	30	165 ↑	425 ↑	1580 ↑
Synthetic rainwater	265	790 ↑	870 ↑	1130 ↑	1920 ↑
Rainfall water	55	155 ↑	260 ↑	480 ↑	1500 ↑
1% by wt. $CaCl_2$ solution	4250	4300 ↑	5000 ↑	5750 ↑	6000 ↑
1% by wt. NaCl solution	20	70 ↑	130 ↑	380 ↑	1480 ↑

Note: ↑ [Total hardness] increases

↓ [Total hardness] decreases

Table I-5. The Concentrations of Iron Total in the Solutions in mg/l

		$[Fe_{total}]$ after submersion of Aggregates :			
TYPE OF SOLUTION	INITIAL $[Fe^{2+}, Fe^{3+}]$	BLAST FURNACE SLAG		STEEL SLAG *	
Distilled water	0.07	1.5	↑	2.2	↑
Synthetic rainwater	0.14	2.4	↑	2.3	↑
Rainfall water	0.09	2.3	↑	2.3	↑
1% by wt. $CaCl_2$ solution	0.20	0.38	↑	2.0	↑
1% by wt. NaCl solution	0.04	0.4	↑	2.3	↑

Note: ↑ $[Fe^{2+}, Fe^{3+}]$ increases

↓ $[Fe^{2+}, Fe^{3+}]$ decreases

* samples develop white, cloudy material which settles with time.

6. Concentrations of Nitrate in the solutions

The results of the test are given in Table I-6. For limestone and blast furnace slag, the concentrations of nitrate decreased after the tests. For traprock and steel slag, the concentrations of nitrage after the tests depended on the type of solution.

7. Concentrations of sulfate in the solutions

The results of the test are given in Table I-7. Except for steel slag in rainfall water, all of the concentrations of sulfate increased after the tests.

I-6 ANALYSIS PROCEDURES FOR THE HACH DIRECT READING ENGINEER'S LABORATORY KIT

The following are the procedures of chemical analysis performed in the study, provided by Hach DR-EL/2 Methods Manual (25):

1. Carbon Dixoide:

Titration Method for Water and Wastewater
APHA Standard Methods, 13th ed, 92 (1972)

Procedure:

1. Take a water sample by filling a 25-ml graduated cylinder to the 25-ml mark with water directly from the source, if possible.
2. Add one drop of Phenolphthalein Indicator Solution and swirl to mix. If a pink color develops, there is no carbon dioxide present. If a pink color does not develop, proceed with Step 3.

Table I-6. The Concentrations of Nitrate in the Solutions in mg/l

TYPE OF SOLUTION	INITIAL $[NO_3^-]$.	$[NO_3^-]$ after submersion of Aggregates :			
		TRAP-ROCK	LIME-STONE	BLAST FURNACE SLAG	STEEL SLAG *
Distilled water	2.6	1.8 ↓	0.9 ↓	0.9 ↓	11.0 ↑
Synthetic rainwater	74.8	30.8 ↓	35.2 ↓	0.4 ↓	9.2 ↓
Rainfall water	4.0	4.0	2.6 ↓	0.9 ↓	12.4 ↑
1% by wt. $CaCl_2$ solution	1.8	1.1 ↓	1.3 ↓	0.2 ↓	23.8 ↑
1% by wt. NaCl solution	1.8	1.8	1.3 ↓	1.3 ↓	13.2 ↑

Note: ↑ $[NO_3^-]$ increases

↓ $[NO_3^-]$ decreases

* samples develop pinky, cloudy colour material.

Table I-7. The Concentrations of Sulfate in the Solutions in mg/l

		$[SO_4^=]$ after submersion of Aggregates :			
TYPE OF SOLUTION	INITIAL $[SO_4^=]$	TRAP-ROCK	LIME-STONE	BLAST FURNACE SLAG	STEEL SLAG
Distilled water	2	3 ↑	150 ↑	450 ↑	4 ↑
Synthetic rainwater	475	625 ↑	575 ↑	800 ↑	500 ↑
Rainfall water	14	18 ↑	225 ↑	400 ↑	4 ↓
1% by wt. $CaCl_2$ solution	2	4 ↑	29 ↑	450 ↑	4 ↑
1% by wt. NaCl solution	2	3 ↑	55 ↑	350 ↑	3 ↑

Note: ↑ $[SO_4^=]$ increases

↓ $[SO_4^=]$ decreases

3. While constantly swirling the graduated cylinder, titrate the sample in the graduated cylinder with Standard Sodium Hydroxide, N/44, until a light pink color develops which persists for at least 30 seconds.

4. Multiply the number of ml of Standard Sodium Hydroxide, N/44, used by 40 to obtain the mg/l carbon dioxide (CO_2).

2. Chloride:

Mercuric Nitrate Titration Method
for Water and Wastewater
APHA Standard Methods, 13th ed., 97 (1971)

Procedure:

1. Pipet 10.0 ml of the water sample into the 50-ml Erlenmeyer flask.

2. Add the contents of one Diphenylcarbazone Indicator Buffer Powder Pillow and swirl to mix.

3. While constantly swirling the flask, titrate the sample with Standard Mercuric Nitrate until the color changes from yellow to purple.

4. Multiply the number of ml of Standard Mercuric Nitrate used by 50 to obtain the mg/l chloride (Cl). See Note A.

Note:

A. The results may be expressed as mg/l calcium carbonate ($CaCO_3$) or as mg/l Sodium Chloride (NaCl) by multiplying the mg/l chloride (Cl) by 1.41 or by 1.65, respectively.

3. Hardness, Magnesium
and Total:

Titration Method - ManVer® II
for Water and Wastewater
APHA Standard Methods, 13th ed., 179 (1971)

Procedure:

1. Pipet 10.0 ml of the water sample into the 50-ml Erlenmeyer flask.

2. Add 3 drops of Hardness I Solution and swirl to mix.

3. Add the contents of one ManVer II Powder Pillow and swirl to mix.

4. While constantly swirling the flask, titrate the sample with Standard TitraVer Solution, N/50, until the color changes from red to pure blue.

5. Multiply the number of ml of Standard TitraVer Solution, N/50, used by 100 to obtain the mg/l total hardness (as $CaCO_3$). See Note A.

Note:

A. The mg/l magnesium hardness (as $CaCO_3$) can be found by subtracting the amount of calcium hardness from the results of the total hardness test.

4. Iron, Total
1,10-Phenanthroline Method
- FerroVer®
for Water
APHA Standard Methods, 13th ed., 189 (1971)

Procedure:

1. Take a water sample by filling a clean 25-ml graduated cylinder to the 25-ml mark. Pour the sample into a clean sample cell.

2. Add the contents of one FerroVer Powder Pillow and swirl to mix. An orange color will develop if iron is present. Allow at least 2 minutes but not more than 10 minutes for the color to fully develop and proceed with Step 3.

3. Fill another sample cell with about 25 ml of the original water sample and place it in the cell holder. Insert the Iron (FerroVer Method) Meter Scale in the meter and adjust the Wavelength Dial to 510 nm. Adjust the LIGHT CONTROL for a meter reading of zero mg/l.

4. Place the prepared sample in the cell holder and read the mg/l total iron (Fe).

5. Nitrogen, Nitrate

Cadmium Reduction Method -
NitraVer® IV
for Water and Wastewater
APHA Standard Methods, 13th ed., 458 (1971)

Procedure:

1. Take a water sample by filling a clean 25-ml graduated cylinder to the 25-ml mark. Pour into a clean sample cell.

2. Add the contents of one NitraVer IV Powder Pillow, stopper the bottle, and shake vigorously for one full minute. A pink color will develop if nitrate is present. Allow at least 3 minutes, but not more than 10 minutes for the color to fully develop and then proceed with Step 3.

3. Fill another sample cell with about 25 ml of the original water sample and place it in the cell holder. Insert the Nitrate Nitrogen (NitraVer IV Method) Meter Scale in the meter and adjust the Wavelength Dial to 525 nm. Adjust the LIGHT CONTROL for a meter reading of zero mg/l.

4. Place the prepared sample in the cell holder and read the mg/l nitrate nitrogen (N).

6. Sulfate

Turbidimetric Method - SulfaVer® IV
for Water
APHA Standard Methods, 13th ed., 334 (1971)

Procedure:

1. Take a water sample by filling a clean 25-ml graduated cylinder to the 25-ml mark. Pour into a clean sample cell.

2. Add the contents of one SulfaVer IV Powder Pillow and swirl to mix. Allow at least 5 minutes but not more than 15 minutes for the color to fully develop and then proceed with Step 3.

3. Fill another sample cell with about 25 ml of the original water sample and place it in the cell holder. Insert the Sulfate (SulfaVer IV Method) Meter Scale in the meter and adjust the Wavelength Dial to 450 nm. Adjust the LIGHT CONTROL for a meter reading of zero mg/l.

4. Place the prepared sample in the cell holder and read the mg/l sulfate (SO_4).

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