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FINAL REPORT FOR CONTRACT 07307,AID337600

by P.W. Weiblen

Introduction

This report references the published data and presents the new data used in the compilation of the Data Base, Lineament and Bedrock geologic maps of the Hoyt Lakes—Kawishiwi area. The report also provides revised interpretations of the geologic relations of the Duluth Complex in the area which have been made possible by preliminary analysis of the new data obtained in the studies conducted under the terms of the contract.

The individuals who were primarily responsible for different aspects of the study are indicated by authorship to the maps and different sections of this report or in explanatory notes to data.

It should be emphasized that the interpretive aspects of the maps and the report should be under continual scrutiny and subject to revision as new data are obtained and new insights are developed by individuals involved in the on-going studies of the Duluth Complex.

Separate reports for the data base, lineament and bedrock geologic maps are presented in this final report. Only brief explanatory material is presented for the data base and lineament maps because these maps are part of the data base for the map of the bedrock geology.

DATA-BASE MAP OF THE HOYT LAKES–KAWISHIWI AREA, ST. LOUIS AND LAKE COUNTIES, NORTHEASTERN MINNESOTA

by R.W. Cooper, G.B. Morey and P.W. Weiblen

DATA-BASE MAP OF THE HOYT LAKES--KAWISHIWI AREA,
ST. LOUIS AND LAKE COUNTIES, NORTHEASTERN MINNESOTA
by R.W. Cooper, G.B. Morey and P.W. Weiblen

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DATA-BASE MAP OF THE HOYT LAKES--KAWISHIWI AREA, ST. LOUIS AND LAKE COUNTIES, NORTHEASTERN MINNESOTA

by R.W. Cooper, G.B. Morey and P.W. Weiblen

The accompanying data-base map shows all known outcrops in the Hoyt Lakes--Kawishiwi area as compiled from the published and unpublished sources cited in the index to mapping. This constitutes all of the reported mapping that could be obtained for the area during the preparation of the map.

The location of drill holes of various mining companies which have conducted drilling programs in the area are also shown on the data-base map. Almost all of the drilling has been confined to a narrow zone along the basal contact of the Duluth Complex. The locations of all the drill holes shown on the map were provided by the Minnesota Department of Natural Resources. This does not constitute all of the drill holes in the area but rather only those drill holes for which the mining companies had turned data over to the Department of Natural Resources before November 31, 1976.

In the Kawishiwi area the actual extent of outcrops was not outlined in the course of the initial mapping of the Gabbro Lake quadrangle (Green et al. 1966, Phinney, 1969, and Weiblen, 1965). However for those outcrops visited samples or structural information were collected and located on aerial photographs or topographic maps. These locations are shown on the data base map with dots (sample and structural data locations) and crosses (structural data only). These symbols in the Kawishiwi area do not indicate directly areas of extensive or intermittent outcrop, but it is apparent where they are closely spaced that outcrop is extensive. In the Hoyt Lakes region intermittent and extensive outcrop areas were delineated by Bonnichsen in his reconnaissance mapping (see index to the data-base map).

A new outcrop map of an area centered on International Nickel Company's proposed minesite in Sec. 25, T.62N., R.11W. is shown in Figure 1. This is an example of the new data base for the bedrock geology of the Duluth Complex which is currently being acquired in the present mapping program of the Minnesota Geological Survey. Detailed mapping of the area (Cooper and Churchill, 1975) delineated the numerous outcrops many of which could not be shown on the data base map at a scale of 1:48000.

Figure 1. Outcrop map of an area centered on an area in the vicinity of International Nickel's proposed mine-site in Sec. 25, T.62N., R.11W.

To accompany: Data-Base Map of the Hoyt Lakes--Kawishiwi Area, St. Louis and Lake Counties, Northeastern Minnesota.

LINEAMENT ANALYSIS OF THE HOYT LAKES–KAWISHIWI AREA, ST. LOUIS AND LAKE COUNTIES, NORTHEASTERN MINNESOTA

by R.W. Cooper

LINEAMENT ANALYSIS OF THE HOYT LAKES--KAWISHIWI AREA,
ST. LOUIS AND LAKE COUNTIES, NORTHEASTERN MINNESOTA
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Lineament Analysis of the Hoyt Lakes--Kawishiwi Area, St. Louis and Lake Counties, Northeastern Minnesota

by R.W. Cooper

A lineament is a mappable linear feature on a surface, whose parts are aligned in a rectilinear or curvilinear pattern distinct from adjacent patterns and it may reflect a subsurface feature (O'Leary, Friedman, and Pohn, 1976). A lineament may represent the physiographic expression of isolated or continuous landforms. This includes the boundaries of morphologically distinct areas, stream courses and alignment of topographic features such as hills or lakes. Lineaments may represent positive features such as hills or ridges or negative features such as stream courses, valleys, or lakes. General definitions of lineaments (O'Leary, Friedman, and Pohn, 1976) are broad enough to include alignment of aeromagnetic features. Aeromagnetic lineaments were used to aid in compiling the bedrock geology of the Hoyt Lakes--Kawishiwi area and are discussed in the companion report on the bedrock geology.

All lineaments depicted on the Lineament Map of the Hoyt Lakes--Kawishiwi area are topographic features. Since the map represents a preliminary analysis to test the use of lineaments as an aid to geologic interpretation no other type of lineament was mapped. The main reason for initiating a lineament study in this area is the fact that extensive glacial cover obscures much of the bedrock geology. The major use of lineaments is to define subsurface structures that may have no or only a subtle expression as seen on the ground. The subsurface structures may be any of a number of geologic features such as faults, domes, basins, anticlines, synclines, etc. A lineament analysis of an area also helps in extending known geologic relationships into areas where bedrock exposures are sparse or nonexistent. For the present study 1:2400 high altitude blue line air photographs were used. These air photographs were done by Mark Hurd Aerial Surveys, Inc. and are available from the Minnesota Highway Department.

Three categories of lineaments (as seen on the photographs) were distinguished in this study: 1. Pronounced lineaments- those easily identified after only a cursory examination. 2. Less pronounced lineaments- those identified after a short examination of the photograph. 3. Vague lineaments- subtle or interpreted linear features which are identified only after the photograph has been examined in detail.

The map was then divided into cells three miles square. The size of the cell was completely arbitrary. This size was picked mainly to give enough lineaments in an individual cell so that if a preferred lineament orientation(s) was present it would be expressed in a linear histogram of frequency vs. orientation. A computer program was written to compile the data for each individual cell and plot the data in a linear histogram form. Lineament trends were divided into class intervals of six degrees to average out errors in measurement of the lineaments. This procedure also produced histograms that could be visually examined for dominant lineament trends.

The length of each individual lineament was also characterized. The following arbitrary intervals were selected: class of 0-1 miles (0-1.6 km); 1-2 miles (1.6-3.2 km); 2-3 miles (3.6-4.8 km); greater than 3 miles (4.8 km); and much greater than 3 miles. Although this data has not been analyzed future research efforts will be directed toward this end.

One area in the Duluth Complex was chosen to be analyzed in detail for the correspondence of lineament trends with known geology. The area is located along

Spruce Road and includes all or portions of Sections 23, 24, 25, 26, 35, and 36, T.62N., R.11W. and Sections 19, 30 and 31, T.62N., R.10W. It includes International Nickel Company's (INCO) proposed open pit mine and much of the minesite area. The area was chosen because it has a thin and discontinuous mantle of drift providing good exposure, several prominent lineaments, and the area has economic potential in the form of copper-nickel sulfide mineralization. The area was mapped by Cooper and Churchill (1975) at a scale of 1:400 (Fig. 2).

In general there is good correlation between mapped faults and lineaments in the INCO minesite area. Most of the lineaments that correspond with mapped faults are pronounced lineaments (Figs. 2 and 3) with a few being less pronounced. A frequency vs. orientation histogram of all lineaments in the area shows a pronounced peak at N.15°E. with subsidiary peaks at N.33°E. and N.45°E. (Fig. 4). The mapped faults are in two groups. One with an orientation of N.20-26°E. and the other at N.31°-35°E. (Fig. 5). The fault orientations of N.31°-35°E. compare favorably with the N.33°E. peak seen on the lineament histogram. The other fault peaks correlate with the flank of the dominant N.15°E. peak on the lineament diagram.

Most of the faults are contained in or border units of the troctolitic series (tcz, tt, and ta). The lineament histogram for these three units displays a broad dominant peak at N.12-24°E. with subsidiary flanking peaks at N.3°E. and N.33°E. (Fig. 6). The fault directions again fall within the prominent peak or a secondary peak. The histogram for the Anorthositic series rocks (ago and agu) shows a strong N.15°E. direction with a secondary peak also present at N.15°W. (Fig. 7). The other peaks present in the histogram are not considered significant because of the few observations.

In summary there appears to be a good correlation between lineament and inferred fault orientation in the INCO minesite area. The predominance of the N.15°E. direction is probably due to the influence of glacial activity which trended north-northeast in the entire Hoyt Lakes--Kawishiwi area (Wright, 1972 and Stark, 1974). This must be taken into consideration when analyzing lineament data because it may obscure other lineament trends more closely related to bedrock control. Although the direction of glacial activity may have been in part controlled by the pre-glacial northeast trending bedrock structure.

For a general lineament analysis the Duluth Complex was divided into two areas. A northern area where drift is discontinuous and relatively thin (0-6 m) and a southern area in which extensive (3 to 13 m) drift is present (Stark, 1974). The northern area is a 7 to 14 km wide band along the base of the complex from Hoyt Lakes to the eastern edge of the Gabbro Lake quadrangle. It also includes most of the known outcrops in the Hoyt Lakes--Kawishiwi area (Cooper, 1976). The southern area contains only scattered exposures and includes the rest of the area inferred to be underlain by the Duluth Complex.

The histogram for the northern area (Fig. 8) displays a broad double peak from N.18°E. to N.42°E. One peak is at N.21°E. and the other at N.39°E. These peaks correspond well with inferred faults in this part of the Duluth Complex. There is a minor peak at N.3°W. which does not correlate with any of the known geologic features in the area. The histogram for the southern or drift covered area (Fig. 9) exhibits a prominant peak from N.33°E. to N.45°E. with a flanking peak at N.21°E. The dominant peak probably represents the trend of Quaternary glaciation as expressed by the Toimi drumlin field. This is a slightly more northeasterly trend than

that indicated from glacial striations on bedrock exposures in the northern area (Stark, 1974).

Comparing the trends in the southern and northern areas shows some overlap of the prominent peaks. The flanking N.21°E. peak in the southern area probably reflects bedrock faulting in that it matches well with the N.21°E. peak in the northern area and the mapped faults in the INCO minesite area. The N.39°E. and N.33°-45°E. peaks in the northern and southern areas do not match that well with the N.33°E. (average direction) faults in the INCO minesite area. It does however indicate that faulting in this general direction (N.30°-40°E.) may be present throughout the area. The correspondence of inferred faulting with northeast lineament trends in the northern area indicates that the northeast trend in the southern area is the result of two controlling factors. The northeast trending faults in the area produced a northeast trending structural grain prior to glaciation and the NE-SW trend of glaciation greatly enhanced this northeast grain. The Toimi drumlin field present in the southern part of the map may have been in part controlled by the structure in the underlying bedrock.

There are some northwest trending structures in the southern area as evidenced by faults, known only on the basis of subsurface information, along the western margin of the Duluth Complex. This is further substantiated by northwest trends exhibited by the aeromagnetic maps of the area (Meuschke et al., 1963; Bath, Schwartz and Gilbert, 1965; U.S. Geological Survey, 1969). The absence of these trends on the lineament map can possibly be explained by the northeast trend of Quaternary glaciation which probably enhanced all northeast trending structures and may have all but eliminated any surface expression of the northwest trending structures.

To further substantiate the idea that lineament trends in the Duluth Complex represent faults, a lineament analysis was undertaken in the Lower Precambrian rocks exposed in the area. These rocks are exposed north and west of the Duluth Complex and form the footwall for the Duluth Complex over much of the exposed contact. The glacial cover is thin and exposures are numerous. For convenience the Lower Precambrian rocks were divided into two large units. The "granitic" rocks of the Giants Range batholith and Vermilion massif make up one unit. The metavolcanic and metasedimentary rocks of the Ely Greenstone, Knife Lake Group, Lake Vermilion formation and Newton Lake formation comprise the second group.

The lineament histogram of the "granitic" rocks (Fig. 10) has a broad peak from N.20°E. to N.40°E. This corresponds almost exactly with the predominance of mapped fault directions (Fig. 11) in these rocks as determined from the maps of this area by Sims (1973) and Morey and Cooper (1977).

The metavolcanic and metasedimentary rocks have several prominent lineament trends oriented at N.24°E., N.39°E., N.57°E. and N.85°E. (Fig.12). The most pronounced of these is the N.57°E. trend. The histogram of mapped faults (Fig. 13) shows prominent trends at N.21°E., N.33°E., N.57°E., N.70°-75°E. and N.87°E. These show good correspondence with the lineament trends in Figure 12. This is especially true when it is taken into consideration that class intervals of six degrees were used to plot the data on the histogram. This means that the accuracy of any peak is ±3 degrees. For example the N.24°E. lineament peak and the N.21°E. fault peak could be expressions of the same trend.

In summary the lineament studies discussed above which were based on the data on the Lineament Map of the Hoyt Lakes--Kawishiwi map indicate the usefulness of a

study of aerial photographs as an aid in geologic mapping and interpretation in glaciated areas. The close correspondence of lineament trends with fault trends in the Lower Precambrian indicates that many of the lineament trends in the Duluth Complex are probably controlled by faults.

A more detailed analysis of lineament trends in the Hoyt Lakes–Kawishiwi area could be used to further define critical areas for mineral exploration and delineate areas that might need more study to substantiate geologic interpretation. Lineament analysis might also be a means of determining alternative geologic interpretations and extending known geologic relations into areas with little or no exposures. An example of the possible relationship between lineaments and the sulfide mineralization in the Duluth Complex is the fact that both the proposed INCO mine and the AMAX mineralized zone lie near prominent lineaments that have been mapped or inferred to be faults (Cooper and Churchill, 1975 and Morey and Cooper, 1977). A lineament study may also be an aid to understanding the movement of groundwater in an area. It is also apparent from the analysis of the Toimi drumlin field discussed above that another important aspect of this type of study is the analysis of glacial features.

Figure 1. Outcrop map of an area in the vicinity of International Nickel's proposed minesite in Sec. 25,T.62N., R.11W.

To accompany: Report on Lineament Analysis of the Hoyt Lakes—Kawishiwi Area, St. Louis and Lake Counties, Northeastern Minnesota.

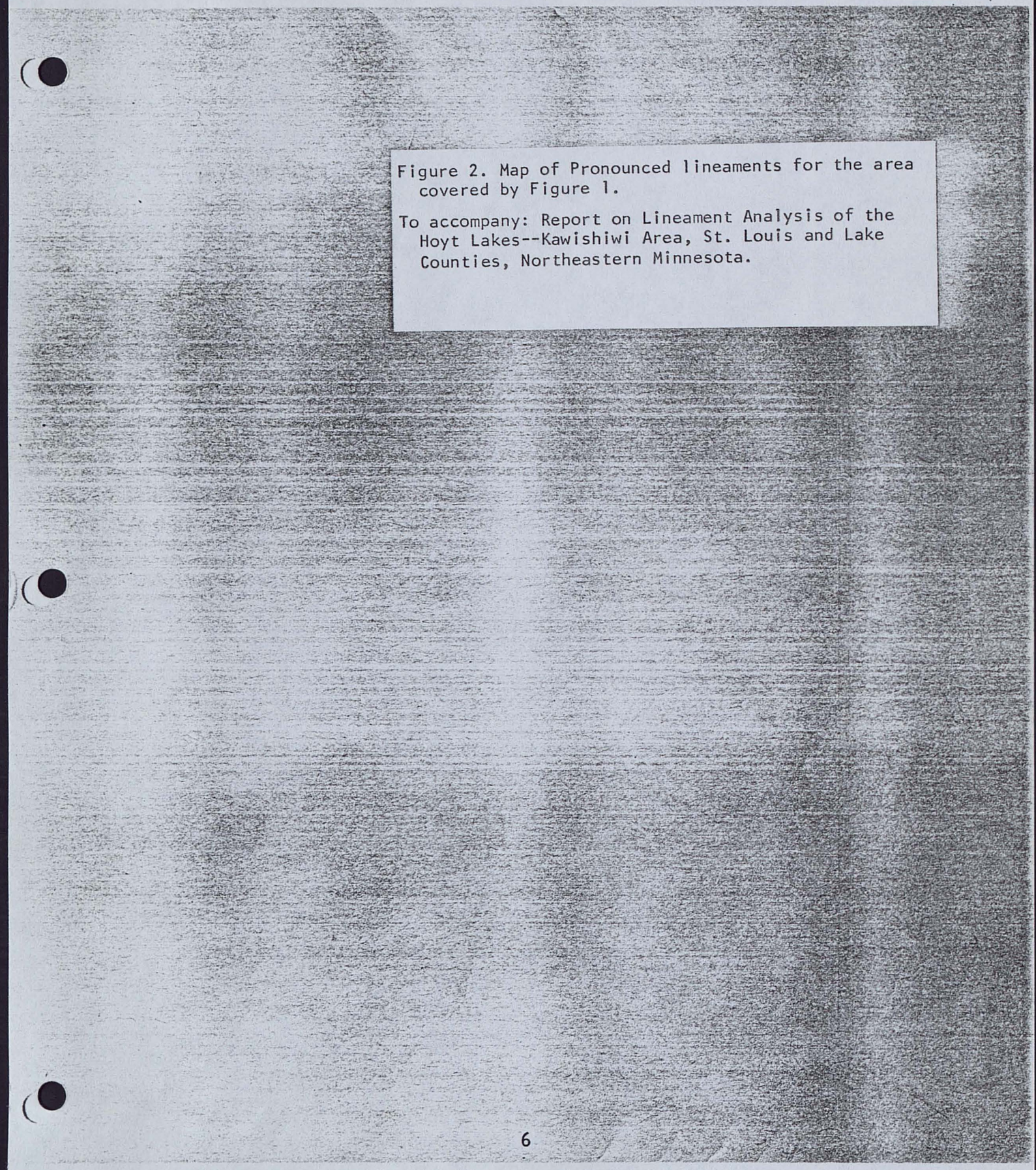


Figure 2. Map of Pronounced lineaments for the area covered by Figure 1.

To accompany: Report on Lineament Analysis of the Hoyt Lakes--Kawishiwi Area, St. Louis and Lake Counties, Northeastern Minnesota.

Figure 3. Geologic map of the area covered by Figure 1.

To accompany: Report on Lineament Analysis of the Hoyt Lakes--Kawishiwi Area, St. Louis and Lake Counties, Northeastern Minnesota.

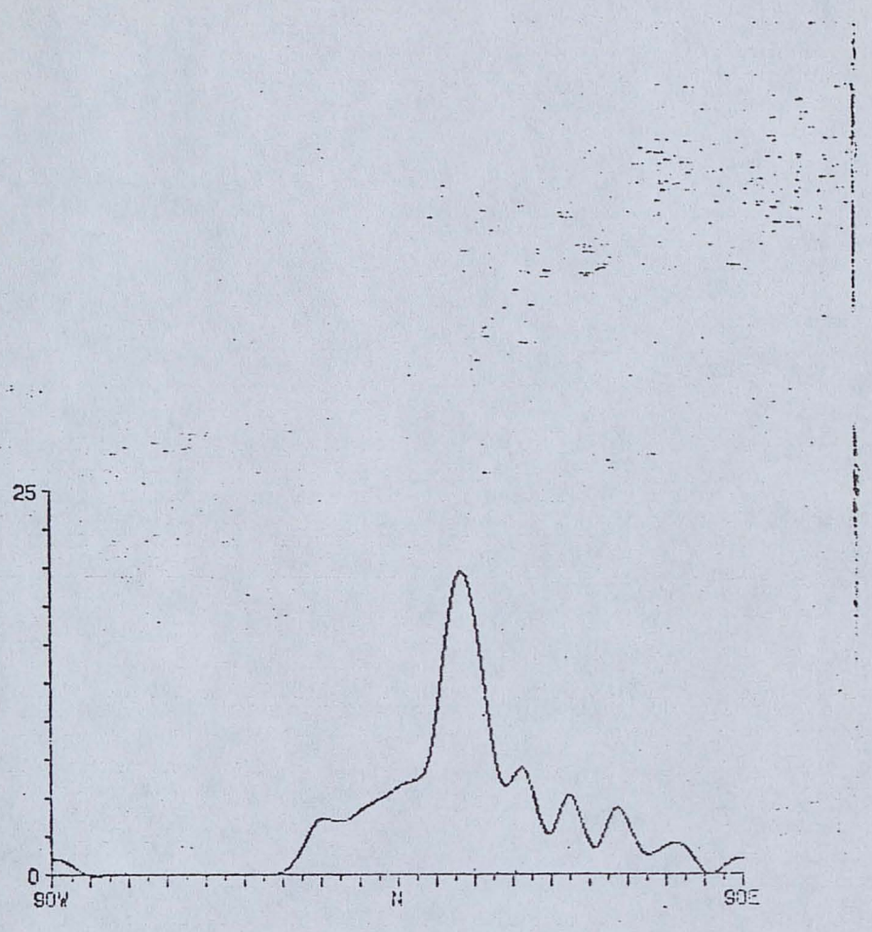


Figure 4 - Cartesian histogram of lineament frequency vs. orientation of all troctolitic and anorthositic series rocks in Figures 2 and 3.

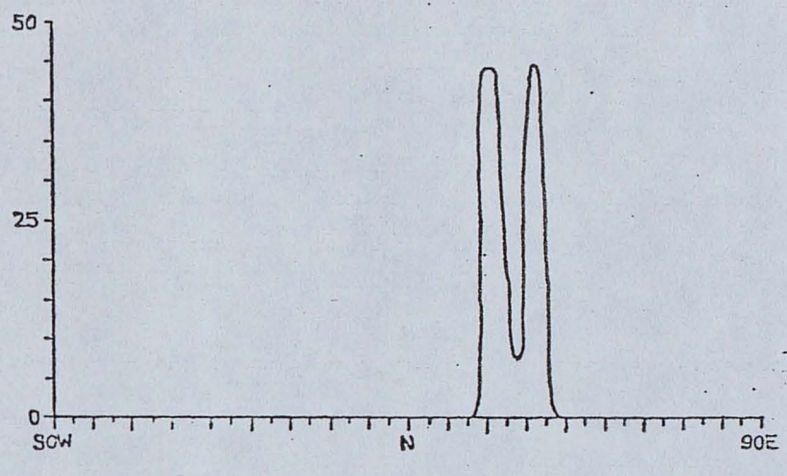


Figure 5 - Mapped fault frequency vs. orientation diagram in the area of Fig. 2.

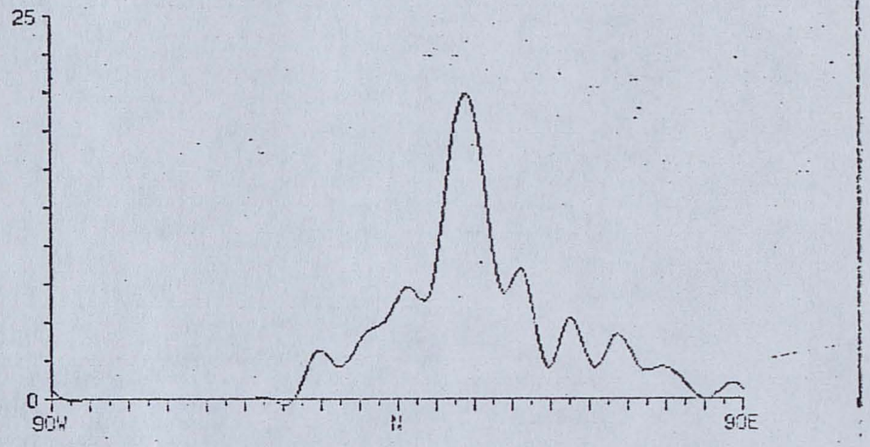


Figure 6 - Lineament frequency vs. orientation diagram of tractolitic series rocks in the area of Figures 2 and 3.

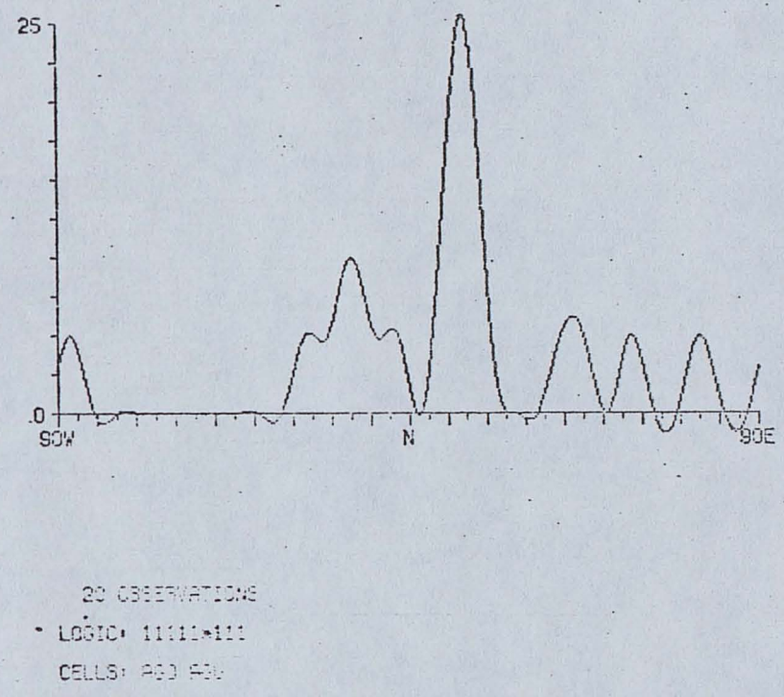
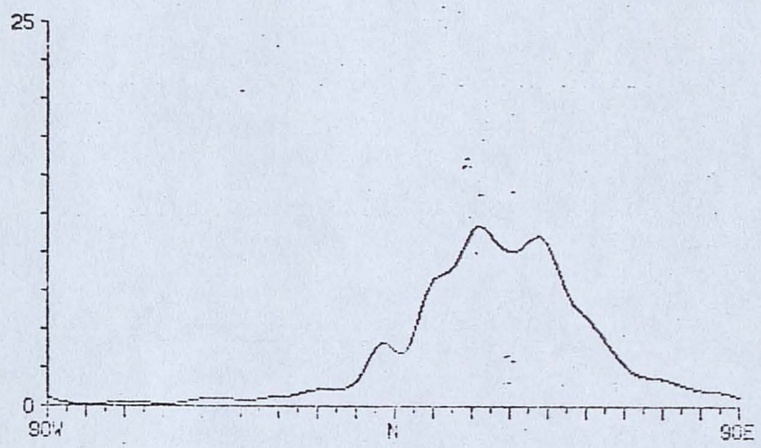


Figure 7 - Lineament frequency vs. orientation diagram of anorthositic series rocks in Figures 2 and 3.



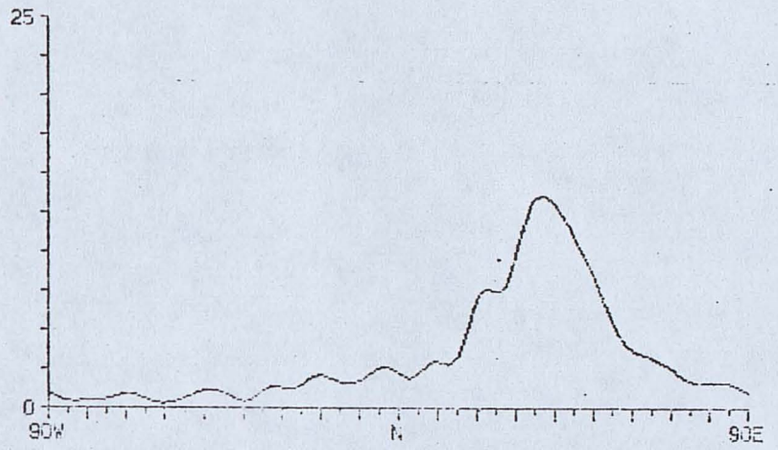
1631 OBSERVATIONS

LOGIC: 11111+111

CELLS: C11 C12 D11 D12 E 9 E10 E11 E12 F 8 F 9 F10 F11 F12
C 7 C 8 D 7 D 8 E 7 E 8 F 5 F 6 F 7 G 4 G 5 G 6 H 3

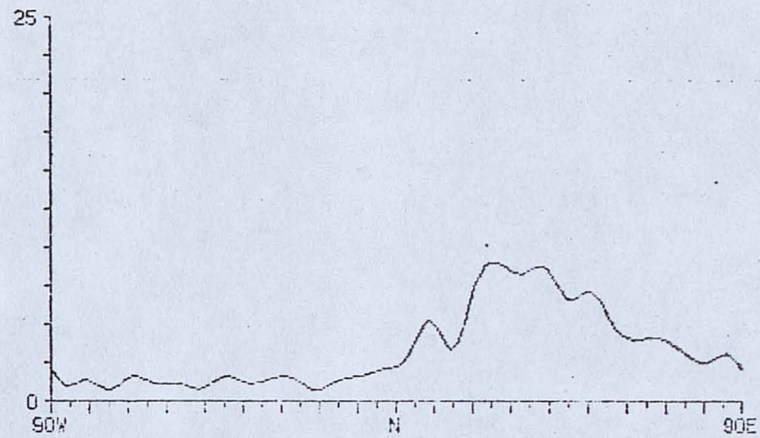
Northern Duluth Complex - exposed

Figure 8 - Lineament frequency vs. orientation diagram of the ~~northern Duluth Complex including most of the known~~ outcrops. The southern limit of this area is approximated by the limit of extensive exposure on the map of the bedrock geology.



Southern Duluth Complex

Figure 9 - Lineament frequency vs. orientation diagram of the southern Duluth Complex in the Hoyt Lakes-Kawishiwi area.



1386 OBSERVATIONS

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CELLS: [illegible]

Vermilion Massif and Giants Range

Figure 10 - Lineament frequency vs. orientation diagram of the Giants Range batholith and Vermilion massif.

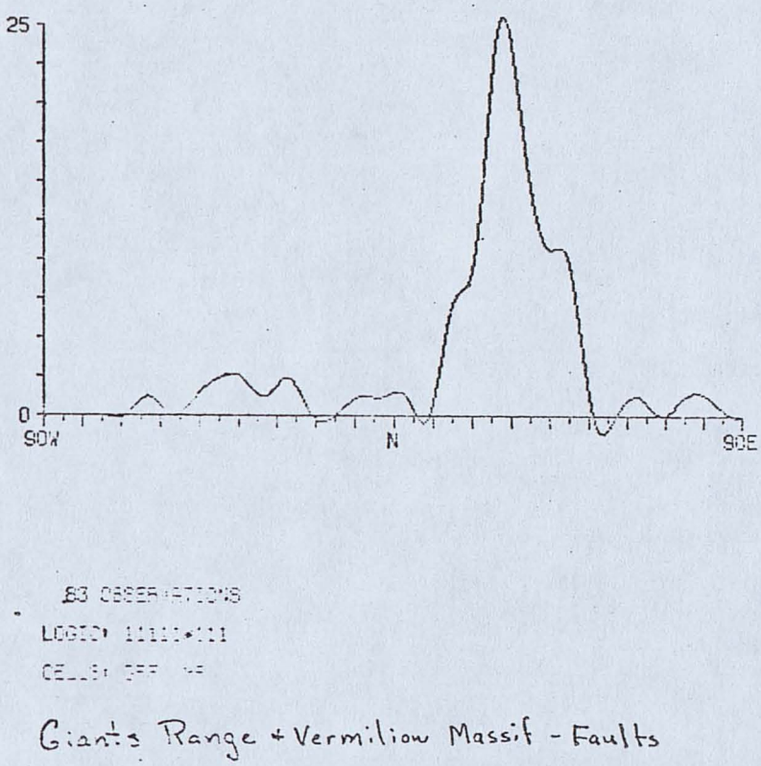
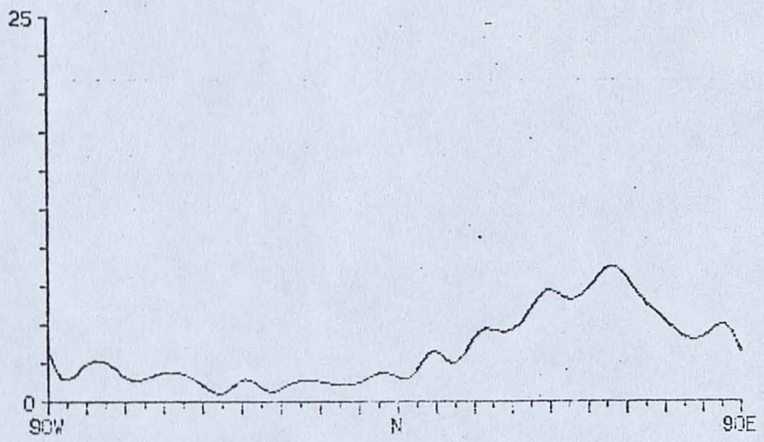


Figure 11 - Fault frequency vs. orientation diagram for the Giant's Range batholith and Vermilion massif.



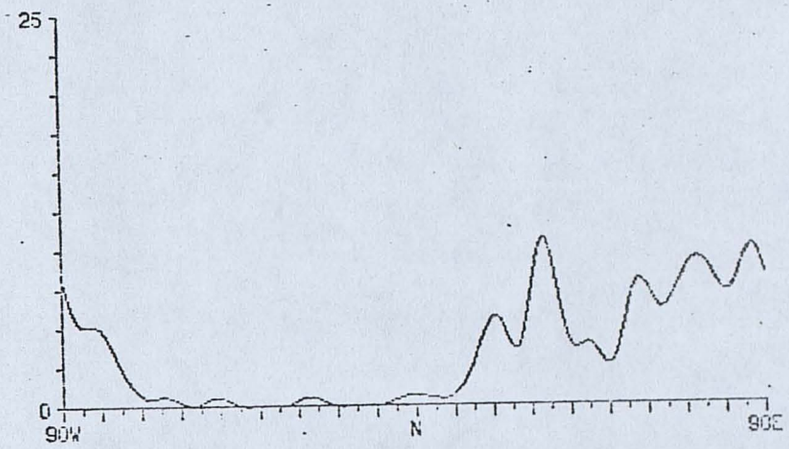
901 OBSERVATIONS

LOGID: 11111+111

CELL#: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
C 5 C 6 D 4 D 5 F 2 F 3 G 1 G 2 G 3 G 4 H 1 J 3

Ely Greenstone, ~~and~~ Lake Vermilion fm, Knife Lake Group, Newton Lake fm.

Figure 12 - Lineament frequency vs. orientation diagram of Lower Precambrian metavolcanic and metasedimentary rocks.



178 OBSERVATIONS

LOGID: 11111*111

CELLS: LVF KLF NLF EGF

Lake Vermilion Fm., Knife Lake Fm., Newton Lake Fm. and Ely Greenstone - Faults

Figure 13 - Fault frequency vs. orientation diagram of Lower Precambrian metavolcanic and metasedimentary rocks.

BEDROCK GEOLOGY OF THE HOYT LAKES--KAWISHIWI AREA

by P.W. Weiblen and R.W. Cooper

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I. Descriptive Geology

A. General Geology

A summary of the nature and extent of geologic mapping in the Duluth Complex prior to 1975 has been compiled by Weiblen and Morey (1975) (Appendix 1). This report contains a complete list of references on the Duluth Complex up to 1974; subsequent work is referenced in this report.

Recognition of distinctive rock types and definition of their areal extent was the principal goal of all the mapping projects up to the present. Rock types were distinguished by 1) color, 2) proportions of the minerals olivine, plagioclase, pyroxene, iron-titanium oxides and sulfides, and 3) the grain size and textural relations of the minerals to each other that could be recognized in the field (Appendix 1, p. 2-4). The areal extent of rock units consisting of a single or dominant rock type was determined by mapping four types of contacts: 1) those between presumed layered units within a single intrusion (stratigraphic contacts), 2) those which define the boundary between separate intrusions (intrusive contacts), 3) contacts between inclusions and their host rocks, and 4) fault contacts.

The term rock series has been used interchangeably with rock unit in the literature on the Duluth Complex, principally to refer in a general way to rock units consisting of a distinctive suite of rock types found throughout the Complex. Both rock unit and rock series are strictly rock classification terms. The terms intrusion and inclusion on the other hand carry genetic connotations. The former refers to a mappable volume of genetically related rocks which are presumed to have formed from one intrusive volume of magma and are younger than the surrounding rocks they intrude. The latter refers to preexisting rocks which were engulfed in a volume of magma and hence are older than the surrounding host rocks. Intrusions and inclusions may consist of more than one rock series.

The most distinctive rocks in the Duluth Complex unfortunately make up only a small proportion of the Complex. They are the isolated masses of red rocks of granitic composition which range in grain size from fine-grained, massive granophyres to coarse-grained varieties of granite all referred to as the felsic series (Appendix 1, p. 8), and the minor exposures of black, coarse-grained dense, olivine-clinopyroxene-ilmenite peridotite (Appendix 1, p. 6). The bulk of the rocks in the Complex consist of a wide variety of grey, plagioclase-rich (60-100%) gabbroic rocks (Appendix 1, p. 2-4). All the mapping has consistently shown that for rock units of mappable size (several km^2) in which plagioclase makes up more than 80% of the rocks, olivine occurs interstitially to the plagioclase (Fig. 3C). In rocks in which plagioclase constitutes less than 80% of the rock, olivine is part of the framework which encloses the other minerals (Fig. 3D). These observations along with some evidence of cross-cutting relationships have led to the conclusion that there are two extensive rock units in the Duluth Complex (Appendix 1, p. 6). One referred to as the anorthositic series consists of anorthosite (90% plagioclase) through troctolitic (minor olivine) or gabbroic (minor pyroxene) anorthosite (80% to 90% plagioclase). The other referred to as the troctolitic-gabbroic series consists of rocks with 60-80% plagioclase with varying proportions of olivine, pyroxene and iron-titanium oxides. The overall extent of peridotite and felsic, anorthositic and troctolitic-gabbroic series rocks is shown on a generalized map of the Duluth Complex

(Appendix 1, p. 5). This map shows that: 1) peridotite is exposed only at Duluth; 2) felsic series rocks occur in isolated masses which cut anorthositic series rocks or lie between anorthositic and troctolitic-gabbroic series rocks, and 3) the anorthositic rock series overlies the troctolitic-gabbroic rock series. These relationships have been found throughout the Duluth Complex (Appendix 1, p. 6-14).

A basic problem posed by the geology of the Duluth Complex as presently known is the delineation of the extent of individual intrusions. For example, is the extensive unit of anorthositic series rocks shown on the generalized map of the Duluth Complex (Appendix 1, p. 5) all one intrusive mass, or does it consist of a series of individual volumes of rock which were emplaced throughout the Complex at different times? Because the rocks formed by crystallization from intrusive magmas, it is possible that magmas of similar composition could have been emplaced in restricted volumes and crystallized under similar conditions but at different times. Such a mode of magma emplacement would give rise to a composite mass of similar rocks which would be mapped as a single intrusion if individual intrusive contacts were obscured. The concept of a single intrusion for the anorthositic series rocks is based on the assumption that all the covered areas between exposures of these rocks are continuous. It is entirely possible, however, that the contacts between individual intrusions of anorthositic series rocks are in fact all obscured.

In the mapping of individual intrusions within the Duluth Complex, intrusive contacts were drawn either on the basis of extrapolation between outcrops with observable cross-cutting relationships or on the assumption that such contacts could be inferred from a change in rock types on either side of a covered area. Such inferred contacts could of course be any of the types of contacts referred to above. The assumption that most are intrusive or stratigraphic contacts is seriously challenged by recent mapping in the Hoyt Lakes--Kawishiwi area which has shown that faulting is an important aspect of the geology of the Duluth Complex (Cooper, 1974, 1975 and Cooper and Churchill, 1975). This is discussed further in the section on interpretive geology.

Within the Hoyt Lakes--Kawishiwi area it has been possible to map intrusive contacts between troctolitic-gabbroic series and anorthositic series rocks. Unfortunately in no instance do these contacts outline the complete perimeter of any single intrusion. The best defined intrusion, the Bald Eagle intrusion in the Gabbro Lake quadrangle, (Appendix 1, p. 12, fig. 3) is defined on only three sides and in addition, the contact along its northern extremity is interrupted by a dike-like feature which connects it with rocks of similar aspect to the southwest referred to as the South Kawishiwi intrusion (Appendix 1, p. 12). This intrusion in turn, is defined by contacts only at its base and along its eastern limit. Its southern limits are obscured by glacial drift, and the question of whether the troctolitic-gabbroic rocks to the southwest are uninterrupted by intrusive or fault contacts has not been resolved. Similarly, distinctive troctolitic-gabbroic intrusions in the Dunka River-Hoyt Lakes area (the Railroad Troctolite and Partridge River Troctolite) mapped by Bonnichsen (1974) are of unknown overall extent, and their relationship to the South Kawishiwi intrusion or all the troctolitic-gabbroic rocks which have not been included in any specific intrusion (referred to in this report as troctolitic rocks undivided) is unknown.

B. Bedrock Geology of the Hoyt Lakes--Kawishiwi Area

The bedrock geology was compiled and modified from published and unpublished data cited in the index to mapping of the accompanying map of the bedrock geology of the Hoyt Lakes--Kawishiwi area, St. Louis and Cook Counties, northeastern Minnesota. Also used in compiling and interpreting the geology of the Duluth Complex were the lineament map of Cooper (1976a) and several aeromagnetic maps of the area (Meuschke, et. al., 1963; Bath, Schwartz, and Gilbert, 1965; and U.S. Geological Survey, 1969). The symbology used in this report follows the map explanation. The term Hoyt Lakes--Kawishiwi area is used in this report to refer to the actual areal coverage of the accompanying map of the bedrock geology.

The Lower and Middle Precambrian rocks will not be described in this report and the reader is referred to the published and unpublished sources cited in the index to mapping for additional information.

Upper Precambrian rocks exposed or inferred to be present in the Hoyt Lakes--Kawishiwi area are represented by the North Shore Volcanic Group, metasedimentary and metavolcanic inclusions in the Duluth Complex, the Duluth Complex, and minor diabasic rocks.

1. North Shore Volcanic Group, undivided (b)

Although no exposures of North Shore Volcanic Group rocks are present in the map area they are inferred to be present in the extreme southeast part of the Brimson and Greenwood Lake quadrangles on the basis of aeromagnetic data (Bonnichsen, 1971). Actual exposures of the North Shore Volcanic Group are found immediately southeast of the map area. These exposures consist of felsic volcanic rocks, magnetite-rich basalt and sedimentary rocks (Bonnichsen, 1971).

2. Inclusions (h,if)

Metamorphosed inclusions found in the Duluth Complex are considered in this report to be of Late Precambrian age regardless of the original age of the rock. The main reason for this is the fact that the metamorphism that they have undergone occurred as a result of the intrusion of Duluth Complex. Metamorphosed inclusions are found along the entire basal contact of the Duluth Complex from the Whiteface Reservoir area in the south to the area of the North Kawishiwi River in the BWCA on the north. They consist of metavolcanic and metasedimentary rocks. For the purposes of the geologic map these rocks were collectively designated as hornfels undivided (h) because it is difficult to determine the original parentage of these rocks in the field. The Biwabik-type iron-formation inclusions (if) were designated separately because their very distinctive quartz-magnetite-iron silicate mineralogy and characteristic bedding have been preserved and they are readily recognizable in the field. Four distinctive hornfels occurrences in the Hoyt Lakes region have recently been studied by Tyson (1976). Based on their mineralogy which is derivable from basalt and relict flow features, he has concluded that all are metamorphosed North Shore Volcanic Group basalts. The location and major characteristics of these occurrences are

summarized in Table 1. Many similar hornfels have been encountered in drill holes throughout the Babbitt--Hoyt Lakes area (Bonnichsen, 1972a and 1974). The size of the inclusions varies from less than a meter to a kilometer or more across.

The bulk of the hornfels inclusions mapped along the basal contact of the Duluth Complex in the Hoyt Lakes--Kawishiwi area are probably of metasedimentary origin. They most likely represent inclusions of Virginia Formation that forms the footwall in the Babbitt--Hoyt Lakes area. They are characterized by locally recognizable bedding which is reflected by a planar distribution of plagioclase and mafic minerals. In thin section their mineralogy differs from metavolcanic hornfels in that they consist of 60-80% plagioclase and varying amounts of hypersthene, cordierite, biotite and/or chlorite (Renner, 1969). The metamorphic grade varies from lower greenschist to pyroxene hornfels facies containing cordierite (Renner, 1969, Bonnichsen, 1972a). Some of the hornfels found in the Kawishiwi area is similar to the metasedimentary variety of the Babbitt--Hoyt Lakes area although no footwall of Virginia Formation is present. These inclusions may represent a thin unit of Virginia Formation that has been completely disrupted and caught up in the Duluth Complex. In the Kawishiwi area a unit informally referred to as the Spruce Breccia (Wager et al., 1969) contains greater than 30% hornfels inclusions. Most of these represent metasedimenary rocks. The Spruce Breccia has been found in the contact zone from Birch Lake to Filson Creek in Sec. 19, T.62N., R.10W. and has been encountered extensively in drill core.

Biwabik-type iron-formation inclusions are found throughout the Hoyt Lakes--Kawishiwi area in the contact zone. The inclusions vary in size from less than a meter in diameter to one hundred or more meters across. They have retained the characteristic bedding of iron-formation. Quartz and magnetite are recognizable in hand specimen, but characterization of the iron-silicate mineralogy has not been made. The largest inclusions occur some distance from the contact zone in Sec. 30, T.62N., R.10W. near Omaday Lake where a large (700 x 100 meters) inclusion of meta iron-formation is bounded on the south and east by a larger body of hornfels of uncertain origin.

Some hornfelsic rocks of the contact zone in the Kawishiwi area appear to be recrystallized fine-grained troctolite or gabbro based on preliminary petrographic examination. This is particularly true of part of the large hornfels body located in Secs. 29 and 30, T.62N., R.10W. between Omaday Lake and Nickel Lake referred to above (Appendix II, fig. 1). Hornfels in unions of this type could represent chilled marginal rocks of early troctolitic-gabbroic intrusions which have been included in later intrusions.

Small meter-sized hornfels inclusions have been found at scattered localities throughout the entire area, some as far as 0.6 km from the basal contact. The origin of these inclusions in not known.

Granitic inclusions probably derived from the Giants Range batholith have been described from drill core (Bonnichsen, 1974) but none have been found at the present erosional surface.

3. Anorthositic Series Rocks

On the map of the bedrock geology of the Hoyt Lakes-Kawishiwi area and in this report peridotite (p) and felsic rocks (f) have been included in the anorthositic rock series following the petrogenetic and stratigraphic interpretation of Weiblen and Morey (1975, Appendix 1, p. 18).

a. Peridotitic and noritic rocks (p)

Peridotite and noritic rocks are found locally in the Hoyt Lakes-Kawishiwi area. The best exposures of norite are those on Gabbro Lake in Secs. 9 and 16, T.62N., R.10W. They consist of approximately 65% plagioclase (An_{35-46}) and 24% hypersthene with augite, opaques and biotite present in minor amounts (Phinney, 1969). The norite at these localities cuts other rocks (aga) of the anorthositic series. Norites have also been described from drill core in the basal contact zone of the troctolitic series rocks, but these are probably related to the troctolitic-gabbroic rather than to the anorthositic series.

Small meter-sized masses of pyroxene-oxide-olivine peridotite have been found in Sec. 23, T.60N., R.12W. and Sec. 17, T.59N., R.13W. along the Erie Mining Company railroad. The occurrence in Sec. 23 has been interpreted as a dike cutting a metavolcanic hornfels inclusion (Bonnichsen, 1974, personal communication). The hornfels in Sec. 23 is surrounded by troctolitic series rocks, but no contacts have been mapped. The exact relationship (intrusive or included) of these occurrences of peridotite and the norite described above to the troctolitic-gabbroic series or anorthositic series rocks is not clear from the exposures.

Larger volumes of peridotite have been intersected in drill core south of Hoyt Lakes in Secs. 27, 28, and 38, T.57N., R.14W. This occurrence has been referred to as the Water Hen Intrusion (Bonnichsen, 1972a and Mainwaring, 1975). It consists mainly of a layered sequence of dunite, peridotite and troctolite. The relationship of the Water Hen Intrusion to the troctolitic-gabbroic or anorthositic series is obscure although P.W. Weiblen has suggested that it may be a larger example of the minor peridotite exposed at Bardons Peak south of Duluth and postulated to be genetically related to the anorthositic series rocks by an original low-alumina magma composition (Appendix 1, p. 16-18, Weiblen and Morey, 1975).

b. Gabbroic anorthosite (aga) and Anorthositic gabbro (ago, agu)

Anorthositic rocks are the most common rock type in the anorthositic rock series in the region. They have been divided into three units on the basis of texture and composition.

1) Gabbroic anorthosite (aga)--This unit was defined by Phinney (1969) and contains an average of 87% plagioclase

(An_{58-70}), 6% hypersthene and 3% augite as the principal minerals. The only exposures of the unit are near and northeast of Gabbro Lake. It has not been identified elsewhere in the region.

2) Anorthositic gabbro (ago)—This unit is characterized by clusters of oikocrysts of olivine, pyroxene and/or oxide minerals (ago) and has also been identified in the Gabbro Lake and Omaday Lake areas (Appendix II, figs. 2 and 3). Clusters of dark mafic minerals in grey plagioclase give this rock a distinctive texture which is easily recognized in the field. The petrologic origin of the clusters is not well understood but may be due to the crystallization of trapped interstitial magma after plagioclase had already crystallized. The clusters or oikocrysts vary in diameter from 5 to 40 mm but most are 5-20 mm in diameter. The groups of single mafic mineral grains are referred to as clusters, and optically continuous crystals are called oikocrysts. Unfortunately it is commonly very difficult or impossible to determine in the field whether the groups of mafic minerals are clusters or oikocrysts. In field descriptions the term cluster has been used in ambigous cases (Beltrame, 1975).

In Sec. 9, T.61N., R.10W. clusters appear to gradually fade and reappear as one traverses a series of exposures. Therefore the clusters may represent a temporal and spatial localized environment in a magma chamber as the anorthosite crystallized. However this does not negate the value of the unit as a mappable feature which may help to understand the relationships in the anorthositic gabbro as a whole. The age relationship of gabbroic anorthosite (aga) to anorthositic gabbro (ago,agu) is unknown although Phinney (1969) suggested that the former may be older on the basis of an antiformal feature he mapped north of Gabbro Lake.

3) Anorthositic gabbro undivided (agu)—This unit forms the majority of the anorthositic series rocks exposed in the Hoyt Lakes-Kawishiwi area. The average range in composition is 75-88% plagioclase (An_{55-85}), 3-8% olivine (FO_{54-65}) and 4-23% clino- and orthopyroxene. Oxide minerals and biotite are minor consituents (Phinney, 1969, Beltrame, 1975). Plagioclase is usually the only cumulus or primary mineral with all other minerals being interstitial (Appendix II, figs. 4 and 5).

Reconnaissance (1:1000) mapping (Cooper, 1975) of an area centered on Sec. 9, T.61N., R.10W. in the middle of a large area of this unit disclosed the presence of at least five distinctive rock types. They include anorthosite, gabbroic anorthosite, and two textural varieties of anorthositic troctolite to troctolitic anorthosite, one with well-defined clusters of olivine and one without (Appendix II, figs. 6 to 14). The texture of the rocks with clusters of olivine is somewhat similar to that found in ago described above, but pyroxene and oxide clusters are lacking. It should also be noted that traces

of sulfide were found on one of the outcrops in this area. From this it is concluded that much of the area between the Bald Eagle intrusion and the South Kawishiwi intrusion described as agu on the basis of reconnaissance mapping (Green et al, 1966) could be further subdivided with detailed mapping. The anorthositic troctolite present in this area is very similar to some of the troctolitic series rocks present further to the west in the South Kawishiwi intrusion. This indicates that the agu body may, in fact, be broken in places by troctolitic series rocks. It also indicates the need for further mapping in this area as other instances of troctolitic-appearing rocks in this general area were noted by Cooper, Beltrame and Dunlavey (1974). The troctolitic rocks found in Sec. 9 have not yet been studied, so it is not known whether they actually are part of the troctolitic series or are simply a more mafic part of the anorthositic series. In the Babbitt S.E. quadrangle, south of the southern limit of exposures, anorthositic gabbro undivided (agu) has been inferred on the basis of aeromagnetic data to overlie troctolitic-gabbroic rocks (Bath et al., 1965, and U.S.G.S., 1969).

c. Granophyric rocks undivided (f)

Granophyre associated with the anorthositic series rocks is rare in the Hoyt Lakes--Kawishiwi area. Granophyre has been found as dikes in the anorthositic rocks in Sec. 19, T.59N., R.12W. and Sec. 8, T.61N., R.10W. In Sec. 19 a granophyric dike 15 to 20 cm wide cuts anorthositic gabbro (agu). This occurrence is close (100 meters) to a contact between anorthositic gabbro (agu) and troctolitic-gabbroic series rocks (tpg). In Sec. 8 a granophyric dike over 5 mm wide has been noted (Cooper, Beltrame, Dunlavey, 1974). Some small granophyric dikes have also been found in Sec. 33, T.60N., R.13W. These are associated with a hornfels inclusion exposed along the Erie Mining Company railroad (Bonnichsen, 1969). These occurrences of granophyre consist of both fine-grained massive red rock and coarser-grained quartz-feldspar rocks which appear white to yellow in outcrop.

4. Troctolitic-Gabbroic Series Rocks

a. Mixed troctolite and anorthositic rocks of uncertain origin (mta)

In several places in the Hoyt Lakes--Kawishiwi area isolated exposures of mixed troctolitic and anorthositic rocks are found. In the Kangas Bay quadrangle several elongate bodies have been found. They consist of a variable mixture of troctolite and the anorthositic gabbro unit (ago) described above (Phinney, 1967). Other exposures of these rocks define a 0.5 sq. km. plug-shaped body in Secs. 21 and 28, T. 62N., R.10W. These rocks have irregular layering and variable textural relations similar to both the anorthositic series rocks and the troctolitic rocks described below (Phinney, 1969). The origin of these mixed zones is not known although Phinney (1969) suggested that they might represent an intrusive contact zone of the

troctolitic rocks in anorthorsitic rocks.

Southwest of August Lake isolated exposures of flow-textured troctolite are surrounded by isolated exposures of anorthositic rocks. These were interpreted by Phinney (1969) to represent possible dike or sill-like extensions of the Bald Eagle intrusion into anorthositic rocks. On the accompanying map these exposures have been interpreted to represent a northeast trending contact between troctolitic (tt) and anorthositic (agu) rocks.

b. Troctolitic and/or gabbroic rocks undivided (tu)

A line has been drawn on the accompanying map to separate the area of extensive exposures of the Duluth Complex from the area in the southern part of the map where exposures are rare due to a thick mantle of Pleistocene glacial material. All of the known troctolitic exposures in this area have been designated with the notation (tu), and no attempt was made to relate any of the exposures to the units mapped further north. On the basis of interpretations of aeromagnetic maps troctolitic rocks are inferred to underlie part of this largely covered area.

c. South Kawishiwi intrusion of Green et al., 1966

The South Kawishiwi intrusion was informally named by Green, Phinney, and Weiblen (1966) to designate troctolitic-gabbroic rocks exposed in the Gabbro Lake quadrangle. The areal extent of this intrusion has been considerably expanded in this report. It has been subdivided into 5 units: (1) a contact zone of troctolite with sulfide mineralization (tcz); (2) a contact zone of gabbro with sparse sulfide mineralization (tg); (3) troctolite (tt); (4) anorthosite (ta); and (5) troctolite with less than 5% augite (tap).

1) Contact zone rocks (tcz)

The contact zone of troctolitic rocks (tcz) in the Kawishiwi area is 0.5-1 km wide and extends from the north side of Birch Lake on the southwest to a point near the BWCA boundary on the northeast where it appears to end due to faulting. It is characterized by sulfide mineralization and extreme heterogeneity of rock types. The various rock types include dunite, picrite, troctolite, anorthositic troctolite, troctolitic anorthosite, norite, gabbro pegmatite and gabbro (Appendix II, fig. 16). The various rock types range in grain size from fine-grained to pegmatitic with many of the fine-grained rock types appearing to be recrystallized (Appendix II, fig. 15). Various types of hornfels and Biwabik-type iron formation commonly occur as inclusions in this unit. These inclusions were described in an earlier section. Also present as inclusions in and near the contact zone are small (one meter to tens of meters) bodies of anorthositic series rocks. Mineralogic layering and foliation is extremely irregular in the contact zone with no systematic distribution apparent at the surface.

Mapping of the contact zone was done on the basis of the heterogeneity of rock types. When the variety of rock types decreased and the rock became uniform in appearance from one outcrop to another the contact was placed between the apparently uniform rock and the heterogeneous rock types. The extreme variety of rocks in the contact zone made it impossible to map individual units. Gossan is fairly common in the contact zone and is indicative of sulfide mineralization. The sulfide minerals most commonly present are pyrrhotite, chalcopyrite, cubanite and pentlandite. Minor sulfide phases include bornite, sphalerite and pyrite as well as other sulfide minerals present in only trace amounts. For a more complete discussion of the nature of sulfide mineralization the reader is referred to Bonnichsen (1972b) and Weiblen and Morey (1976).

Based on the results of all mapping in the contact zone, the mineralization is apparently not restricted to any single rock type or to specific localities. It has been found sporadically along the entire depth of the exposed part of the contact zone, and the surface expression is usually brown-stained, pitted rock (gossan). The stained and pitted appearance of the gossan is a result of oxidation and solution of sulfide minerals. Detailed mapping (Cooper and Churchill, 1975) in the INCO Minesite area failed to disclose any obvious stratigraphic control on mineralization. The mapping did delineate the presence of a zone of higher sulfide mineralization near faults that were mapped in the area. It also revealed an area of sparse mineralization in the SE ¼, SE ¼, Sec. 25, T.62N, R.11W. that appears to be associated with hydrothermal alteration. Both the mineralization and the hydrothermal alteration lie along a fault zone. These relationships further substantiate the association of faulting and sulfide mineralization. Other scattered instances of traces of sulfide along the mapped faults were found in the southern part of the INCO minesite area (Cooper and Churchill, 1975).

2) Contact zone gabbro south of Birch Lake (tg)

Bonnichsen (1969c) has mapped a unit of gabbro (tg) along the base of the Duluth Complex south of Birch Lake in Secs. 26 and 35, T.61N., R.12W., and Secs. 2 and 3, T.60N., R.12W. It consists of fine- to medium-grained gabbro, norite and troctolite, with variable quantities of olivine and oxide minerals. Hornfels inclusions are common throughout the unit and are especially abundant in the subsurface (Bonnichsen, 1972a and 1974). The unit contains sparse sulfide mineralization but its exact relationship to the tcz unit is unknown. The southwest extension of the tg unit is unknown because of a paucity of exposures.

3) Troctolite (tt)

Troctolite is the most extensively exposed unit of the South Kawishiwi intrusion. It is bounded on the east and

northeast by the anorthositic rock series and the Bald Eagle intrusion. On the southwest it is inferred to be in fault contact with the Partridge River troctolite. The southern boundary is unknown because of lack of exposures but is inferred to be in part rocks of the anorthositic series on the basis of aeromagnetic interpretation. The troctolite is a rather uniform unit in terms of rock types and textures although both vary with distance from and along the stratigraphic contact with the contact units (tg) and (tcz). Parallel to the contact zone a band of troctolite 4 to 5 km wide can be distinguished from the troctolite found further to the southeast. Near the contact inclusions of the anorthositic series rocks (agu) and hornfels (h) are relatively abundant in the troctolite. Whether the anorthositic bodies represent a single sheet(s) or are just isolated remnants of the anorthositic series rocks caught up in troctolitic magma is not clear from the present evidence. The troctolite host rock has an average compositional range of 65-85% plagioclase (An_{57-60}), 8-30% olivine (Fo_{50-55}) and minor amounts of pyroxene (1-6%), oxides (1-8%) and 1-3% biotite (Phinney, 1969; Beltrame, 1974; and this report). The troctolite is very homogeneous in appearance with plagioclase and olivine the only primary or cumulus minerals. All other minerals are interstitial with clinopyroxene commonly poikolitic. Orthopyroxene is commonly present but only in minor to trace amounts. It usually forms a reaction rim around olivine crystals, but rare interstitial grains are also found. Apatite has also been found locally in trace amounts in some of the rocks. Plagioclase commonly has a foliation which in general strikes northeast and dips 10° to 30° southeast. Modal layering of olivine and plagioclase is occasionally found in this area. It almost always parallels the trend of the foliation. The modal layering is usually on the scale of a single outcrop and cannot be traced from one outcrop to another.

Gabbro to olivine gabbro has also been noted at a few localities in the troctolite. These occurrences are confined to single outcrops which are surrounded by troctolitic rocks. Their genetic relationship to the surrounding troctolite could not be determined in the field and they have not yet been studied in detail.

Figures 17 to 20 in Appendix II are representative of the troctolite (tt) along the contact zone. To the southwest in the Babbitt NE quadrangle in Secs. 34 and 35, T.60N., R.12W. the troctolite appears to be layered on a massive scale. Individual layers vary from from troctolite at the base to troctolitic anorthosite or anorthosite at the top of a layer. The modal layers appear to be at least 10 to 30 meters or more in thickness. Whether or not this is true of the troctolite in the Gabbro Lake quadrangle is not known but may indicate that future mapping and study should test the idea that gross layering is present in these rocks.

Southeast of the 4-5 km wide zone described above, the

troctolite changes slightly in texture and mineralogy. Instead of being homogeneous with in general an even distribution of minerals, it has a marked layered appearance (fig. 15). The layering is shown by an accumulation of olivine crystals at the base of each layer that either abruptly or gradually gives way to a more plagioclase rich rock at the top of the layer. The top of the layer commonly contains only minor amounts of olivine. Pyroxene, oxides and biotite are commonly present only in trace amounts throughout an individual layer. An individual layer may be a few centimeters to a meter or more in thickness and usually can be traced a few meters laterally (where the exposures are good) before it pinches out. This indicates that the lateral continuity of single layers is limited. The average range in composition of the layered troctolite is 65-85% plagioclase (An_{57-67}), 10-35% olivine (Fo_{55-62}), and minor amounts of pyroxene (0-2%), oxides (0-4%) and zero to trace amounts of biotite (Phinney, 1969, Beltrame, 1974, and this report). The compositional range for these rocks is very similar to that noted for the troctolite closer to the basal contact. The main differences are the pronounced layering of these rocks and the decrease in the minor phases pyroxene, oxides and biotite. Locally pyroxene content exceeds the range (0-2%) noted above, but this is rare in the exposures that have been examined prior to this report. At one locality in Sec. 18, T.61N., R.10W. an olivine gabbro has been found. This occurrence is similar in nature to the gabbro exposures found closer to the basal contact noted above. This may represent an isolated occurrence of trapped magma that underwent more differention than the rest of the surrounding troctolitic rocks.

On the east side of Heart Lake in Sec. 18, T.61N., R.10W., on a low ridge are several small outcrops of ultramafic rocks. Pyroxene, oxide, and olivine layers of variable thickness make up almost all of some of the outcrops. Picrite and troctolite are also present. Contacts of the ultramafic outcrops with normal troctolite are not exposed, and therefore the relationship with the layered troctolites found to the south, west, and north is not known. The modal layering in these outcrops is highly variable but in general has an attitude of approximately N.40°E., 21°NW.

4) Troctolite with 5% Augite (tap)

Troctolite with less than 5% augite (tap) was mapped by Bonnichsen (1969c and 1971) in the Babbitt NE quadrangle. This unit may be correlative with the layered troctolites exposed in the Harris Lake area. Mapping of the NW ¼ of the Greenwood Lake quadrangle is required to test this correlation.

5) Anorthosite (ta)

Exposures of anorthosite are scattered throughout the troctolitic rocks in the Gabbro Lake quadrangle and the

surrounding area (Appendix II, figs. 21 to 23). In general they all have more than 90% plagioclase and are presumed to represent plagioclase rich segregations within troctolite (Phinney, 1969, p. 17). In Sec. 35, T.60N., R.12W. the texture of the troctolite, like that near the contact zone described above (tt) abruptly changes from having cumulus olivine to interstitial olivine. This is accompanied by a decrease in the olivine content. The amount of olivine gradually decreases stratigraphically upward until the rock consists of 99% plagioclase. The foliation in the troctolite and the troctolitic anorthosite immediately above is parallel and the contact between the two parallels the foliation. It is interesting to note that in this exposure olivine clusters in the more anorthositic rocks appear and fade over a small area. This occurrence is similar to that in the anorthositic series rocks described above.

d. Railroad troctolite of Bonnichson (tr)

The Railroad troctolite (tr) was informally named by Bonnichsen (1974) for the somewhat unique troctolite exposures along the Reserve Mining and Erie Mining Companies railroad tracks in T.59N., R.12W. Here the troctolite is characterized by complex textures and consists mainly of medium-grained augite troctolite, augite oxide troctolite, and oxide troctolite (Appendix II, fig. 14). Foliation is extremely variable throughout the unit. A variety of inclusions are found in the unit and include metasedimentary and volcanic hornfels, troctolites and anorthositic series rocks. It appears to merge with the troctolitic rocks of the South Kawishiwi intrusion to the north, but limited exposure prevents recognition of the true relationship between the two units. The southern limit of the Railroad troctolite is unknown, but on the basis of interpretation of aeromagnetic maps anorthositic series rocks are inferred to be present a few miles south of the last known exposures of troctolite. It is in fault contact with rocks of the Partridge River troctolite on the west.

e. Bald Eagle intrusion of Weiblen, 1965 (tbt, tbg)

The Bald Eagle intrusion of Weiblen (1965) is an intrusion of foliated troctolite (tbt) and gabbro (tbg) located in the SE quarter of the Gabbro Lake and NE quarter of the Greenwood Lake quadrangle. On the accompanying map the overall length of the intrusion has been extended to the south from that originally mapped by Weiblen (1965). This southern addition is covered by glacial deposits and rock types have been inferred on the basis of a similarity of the anomalies with those associated with the exposed part of the Bald Eagle intrusion to the north. The intrusion does not have a chilled margin. Medium to coarse-grained foliated troctolite is either in direct contact with or separated by 1-10 meter wide covered areas from anorthositic series rocks along the western, northern and eastern sides of the intrusion. Based on quantity data and the dip of foliation near the contacts the intrusion is believed to be funnel-shaped at depth with steep dips on the east and somewhat shallower dips (45°-75°) on the west (Weiblen, 1965). The exposed troctolite is

distinctly flow layered with parallel alignment of plagioclase laths and elongate olivine crystals. Olivine and plagioclase are the main cumulus minerals present. Modal layering and foliation are common throughout the troctolite and in general are parallel to the contacts of the intrusion. The foliation of the troctolite dips steeply (75-90°) on the north and east sides and 15° to 75° on the west toward the center of the intrusion. The average composition is 57% plagioclase (An_{62-81}) and 34% olivine (Fo_{71-74}) with clinopyroxene and opaques present in minor amounts (Weiblen, 1965 and Phinney, 1969).

The gabbro (tbg) in the northern part of the intrusion is completely surrounded by troctolite. The average composition is 42% plagioclase (An_{57-67}), 46% clinopyroxene and 10% olivine (Fo_{61-62}). Orthopyroxene, oxides, and biotite are present in trace amounts (Phinney, 1969). The plagioclase laths and elongate olivine and clinopyroxene crystals are aligned and form a prominent foliation. Modal layering is also common and parallels the foliation. The trend of the foliation and modal layering is in general parallel to that observed in the troctolite with dips varying from 10° to 80° towards the center of the intrusion (Weiblen, 1965 and Phinney, 1969). Plagioclase-rich segregations are common throughout the exposed portion of the Bald Eagle intrusion. These may have resulted from flow differentiation during the intrusion of the magma.

On the basis of the interpretations of the lineament studies it has been inferred that the intrusion is largely bounded by faults on both sides and that the intrusion itself is also cut by several faults. These faults are also consistent with the aeromagnetic anomalies associated with the intrusion. Geologic evidence that faults cut the intrusion consists of offsets of contacts (e.g. Sec. 1, T.61N, R.10W.), rather abrupt changes in the trend of foliation (e.g. Sec. 18, T.61N., R.9W.) and serpentization of olivine and pyroxene along the lineaments.

A small plug-shaped body (5 sq. km.) of troctolite (tbt) similar to that found in the Bald Eagle intrusion has been described in Sec. 17, T.62N., R.10W. (Phinney, 1969).

f. Flow layered troctolite and gabbro (tf) and troctolite to gabbro pegmatite (tp)

Between Gabbro Lake and Omaday Lake a dike-like body has been mapped by W.C. Phinney (Green, et al., 1966). The dike consists of two units, an outer unit of flow layered troctolite and medium-grained gabbro (tf) and an inner unit of pegmatite (tp). Also present in the dike are inclusions of Biwabik-type iron-formation, hornfels and undivided anorthositic gabbro which have been discussed in an earlier section. The dike is almost totally surrounded by rocks of the anorthositic series.

The outer part of the dike is very heterogeneous in nature. Flow-layered troctolite (fig. 3; Appendix II, figs. 32 and 33) is present along the southern boundary of the dike near an entry gate to the BWCA at the end of Spruce Road. The layering is due mainly

to variable proportions of olivine and plagioclase and is commonly contorted. This leads to the conclusion that the dike was emplaced as a flowing mass with plagioclase and olivine adhering to the walls (flow layering) forming modal layers that were then crumpled and distorted as magma continued to flow through the center. However near a Forest Service road leading to Omaday Lake in Sec. 30, T.62N., R.10W., medium to coarse-grained oxide gabbro, olivine gabbro, and gabbro are found adjacent to the northern boundary of the dike. Whether this is an inclusion or actually part of the dike could not be determined in the field. The marked difference between the gabbro and the rest of the dike, however, suggests that the gabbroic rocks may be an inclusion (Cooper and Churchill, 1975). The troctolite just north of the western part of Omaday Lake and immediately east and south of the western part of the lake is a layered troctolite similar to the layered troctolite in the vicinity of Harris and Heart Lakes. The trend of the layering is diverse and shallow dips are common. For this reason these rocks were included as part of the (tt) unit of the South Kawishiwi intrusion described above. In general the outer part of the dike can be characterized as a troctolite with 55-65% plagioclase (An_{58-72}), 15-30% olivine (Fo_{55-63}) and 5-10% pyroxene. Oxide minerals and biotite are present in minor and trace amounts respectively (Phinney, 1969, and Cooper and Churchill, 1975).

The central portion of the dike is made up of gabbro to olivine gabbro pegmatite high in oxide minerals. The pegmatite appears to pinch out near Omaday Lake on the southwest and Gabbro Lake in the northeast. The flow layered outer portion (tf) appears to break up into several parts near Gabbro Lake. Its genetic relationship to the troctolite (tt) of the South Kawishiwi intrusion or the Bald Eagle intrusion is unknown.

g. Partridge River troctolite of Bonnichsen, 1974 (tpt)

The name Partridge River troctolite (tpt) was informally used by Bonnichsen (1974) to designate troctolitic rocks near Hoyt Lakes and south of the Reserve Mining Company. Augite troctolite and troctolite are the main rock types present (Appendix II, figs. 25 to 27). The Partridge River troctolite is bounded on the southeast by anorthositic series rocks which are inferred to be present from aeromagnetic data. On the east side it is in fault contact with the Railroad troctolite (tr) and part of the South Kawishiwi intrusion (tt). The southwest extension of the Partridge River troctolite is unknown because of a paucity of exposures although troctolite is the major rock type present in known outcrops.

This general area was examined by Cooper (1976) using the reconnaissance maps of Bonnichsen (1969a-e) as guides. The units observed in the South Kawishiwi intrusion do not appear to be present in this area. The basal contact zone is much more homogeneous in nature than the contact zone of the South Kawishiwi intrusion although zones of inclusions are found (Bonnichson, 1974). The contact zone displays well-developed modal layering from a few centimeters to approximately 10 meters. Because of the sparse

number of exposures the layering could not be traced for any distance laterally. The contact zone is also characterized by sulfide mineralization similar to that found in the tcz unit of the South Kawishiwi intrusion, but the mineralization appears to be present over a wider stratigraphic interval. The exact extent of mineralization and whether there is a genetic relationship of the mineralization with that in the tcz unit is not known.

The modal layering of the contact zone becomes much grosser as distance from the contact increases (moving higher stratigraphically). In Secs. 21, 22, 23, 25 and 26, T.59N., R.13W., a gross stratigraphy of modally layered troctolite was found (Cooper, 1976; Appendix II, figs. 28 and 29). An individual layer was determined to consist of troctolite or picrite at the base giving way to troctolitic anorthosite, anorthositic troctolite, and local anorthosite at the top of the layer. This sequence was than repeated in the next layer although the anorthosite was not always present. The layers vary in thickness from approximately 10 meters to 100 meters, and some may be much thicker. Repetitive layering of this type has been referred to as cyclic layering (Wager and Brown, 1967). Pyroxene content appeared to increase from the bottom troctolitic or picrite to the top of the anorthositic troctolite in some of the cyclic units although this is not always the case. Occasionally the pyroxene content is high enough to classify the rock as an olivine gabbro (Appendix II, fig. 25). It was noted in several places that the pyroxene content is greatest at the base of the cyclic unit and decreases in percent upward but always to a greater extent than the decrease in olivine content. This discrepancy implies that magma may have been intruded in small batches of slightly different bulk composition and allowed to differentiate before the next batch was intruded. Although the bulk composition of the batches of magma may have been slightly different, the bulk chemistry of all the magma may have been quite similar. The plagioclase rich rocks found at the top of some of the cyclic units usually contain little or no olivine and only small amounts of clinopyroxene and oxides.

Troughs or channels approximately 1-2 meters wide were found at several localities in the Partridge River troctolite. The channels were cut into troctolite or anorthositic troctolite and were filled with picrite or troctolite respectively. These represent strong evidence for active currents moving across the floor of the magma chamber in quiescent periods when no crystals were being deposited by gravity settling. Most of the cyclic units appear to be deposited by gravity settling but currents within the magma must have been operative. More detailed field work combined with laboratory studies is needed in this area to characterize in detail the layering described here and if it is definitely of the cyclic type as proposed here, to ascertain whether it is present over a much broader area. This area may prove to be very fruitful for further study because the number of exposures while not great is amenable to detailed study. This is also the only area in the Hoyt Lakes—Kawishiwi region where strong evidence has been found that supports the idea that the Duluth Complex may be in part similar to some classic layered mafic intrusions such as the Skaergaard Intrusion and Stillwater

Complex. The presence of definable cyclic units also helps to highlight the difference between the South Kawishiwi intrusion and the Partridge River troctolite. Bonnichsen (1976, written communication) has suggested that the Partridge River troctolite may be time equivalent to the Bald Eagle intrusion.

h. Powerline gabbro of Bonnichsen, 1974 (tpg)

The Powerline gabbro (tpg) of Bonnichsen (1974) is located in the northwest part of T.59N., R.12W. and adjacent townships south of Reserve Mining Company. It is bordered by the Partridge River troctolite on the west and northwest. The rest of the body is surrounded by rocks of the anorthositic series (agu). Several good exposures of this unit occur along the Erie Mining Company powerline that crosses the body. It is a coarse-grained olivine gabbro containing abundant apatite (Appendix II, figs. 30 and 31). The magnetite content is relatively high and the augite is characterized by abundant opaque inclusions. Bonnichsen (1974) suggested that the unit may be a ferrogabbro and represent a late stage differentiate of the troctolitic-gabbroic rock series.

i. Ferrogabbro of Bonnichsen, 1971 (fg)

Bonnichsen (1971) mapped a number of ferrogabbro (fg) outcrops in the south central part of the Greenwood Lake quadrangle. These rocks are oxide-rich gabbros (Appendix 1, p. 13) with a well developed flat lying foliation due to planar orientation of tabular plagioclase, clinopyroxene and ilmenite. From the texture it appears that these minerals along with minor olivine and apatite all crystallized simultaneously. These textural relationships and a ferrogabbro type would be expected for any differentiated unit which might overlie unit (tbg) in the Bald Eagle intrusion (Appendix 1, p. 13). However, due to the isolated nature of the exposures, it is not possible to include them in the Bald Eagle intrusion or in the Powerline gabbro which they also resemble.

j. Granophyre of Bonnichsen, 1971 (fr)

Bonnichsen (1971) noted a number of granophyre (fr) exposures in the vicinity of Greenwood Lake. They are bordered on the northwest and north by the ferrogabbro (fg) described above, troctolitic and/or gabbroic rocks (tu) and undivided anorthositic gabbro (agu). Volcanic rocks of the North Shore Volcanic Group are found to the southeast which have been described in an earlier section. The granophyre is medium-grained and consists largely of a granophyric intergrowth of quartz and alkali feldspar with minor magnetite. Discrete quartz and plagioclase grains are also present. These rocks may represent the late stage phase of a differentiation trend. Bonnichsen (1972a) surmised that they could be related in this way to the troctolitic-gabbroic series and this relationship has been inferred on the accompanying map of the bedrock geology. They could however be related to the anorthositic series (Appendix 1, p.16-18). Resolution of the problem of their true petrogenetic relationship to other rock units in the Duluth Complex could be

resolved by trace and minor element analysis.

k. Diabasic rocks undivided (d)

Cross-cutting diabasic rocks (d) are found widely scattered throughout the Duluth Complex in the Hoyt Lakes-Kawishiwi area. They consist mainly of basalt or diabase dikes (Appendix II, figs. 34 and 35). The dikes vary in width from less than 30 cm to a meter and appear to be vertical. They cut both the troctolitic-gabbroic and the anorthositic rock series. Their origin and relationship to the Duluth Complex is unknown.

l. New petrologic data on the troctolitic-gabbroic series rocks.

A representative series of samples of the troctolitic-gabbroic series rocks was selected for new detailed microscopic-petrologic studies. Except for a few samples which were collected before 1974, the sample numbers provide the locations of samples on a section basis. For example, sample number 62-11-33-24 refers to sample #24 from Sec. 33, T.62N., R.11W. Locations of samples within sections are given in figs. 1-13 and more detailed descriptive outcrop locations are on file with the Minnesota Geological Survey.

Results of the studies on samples from the Kawishiwi area (figs. 4-13; Appendix II, Part 3) are presented in this report. One set of these samples was chosen to provide new data on variations in the rocks along a traverse normal to the basal contact. This traverse parallels Minnesota Highway 1 (fig. 1). Characterization of samples from the Hoyt Lakes area (fig. 2) will be included in future research projects of the Minnesota Geological Survey on the Duluth Complex. Three aspects of the Kawishiwi samples have been characterized: 1) textures, 2) mineral proportions and 3) mineral chemistry.

1) Textures

The microscopic textures of all the samples have been documented with photomicrographs of the entire area of individual thin sections (approximately two square centimeters) at a magnification of ten times (Appendix II, Part 2).

The photomicrographs in Appendix II, Part 2 confirm that in all the samples studied from the Kawishiwi area, plagioclase and olivine form a framework texture for interstitial clinopyroxene, iron-titanium oxides, sulfides and minor biotite, apatite and K feldspar. Photomicrographs of ferrogabbro from the southeastern part of the map area show that olivine, plagioclase, clinopyroxene, and iron-titanium oxides are tabular in form and thus must have crystallized simultaneously (Appendix II, Part 2, 59-10-31-1Aa). These textural relationships are similar to those found for olivine, plagioclase, and clinopyroxene in the Bald Eagle intrusion (Weiblen, 1965). These similarities suggest that the following crystallization sequence for the troctolitic-gabbroic rocks: olivine-plagioclase-clinopyroxene-iron titanium oxides followed by sulfides

and the minor phases apatite, biotite and/or K feldspar may be ubiquitous for the troctolitic-gabbroic series rocks throughout the Hoyt Lakes--Kawishiwi area.

Parallel lamination of plagioclase is particularly apparent in some samples (for example: 61-10-10Aa and 10Ac; Appendix II, Part 2). From the photomicrographs and the field mapping it appears that this phenomenon becomes better developed with distance from the contact. Three mutually perpendicular thin sections of orientated samples would be required to make a meaningful analysis of this aspect of the troctolitic-gabbroic series rocks.

Grain size measurements of plagioclase were made on the Minnesota Highway 1 traverse samples. Because plagioclase has a tabular form, measurements of grain widths are least susceptible to error or bias due to orientation of thin sections relative to plagioclase lamination in the rocks (fig. 3). The results of the grain size measurements are listed in Appendix II, Part 3, Table 1 and are graphically illustrated in figs. 4 and 5. The frequency distribution of the grain size data shows a normal distribution (fig. 4) which indicates that selection of grains for measurement was not biased toward any particular grain size. There is a regular increase in widths of plagioclase grains from less than a millimeter at the contact to about 3 mm ten kilometers to the southeast for the randomly oriented thin sections (fig. 5). The significance of this new data is discussed in the section on interpretation.

2) Mineral proportions

Data on mineral proportions in the Kawishiwi area samples (modal analyses) were obtained on just those samples along or within one km of the Minnesota Highway 1 traverse. Positive identification of olivine, plagioclase, clinopyroxene, orthopyroxene and biotite were made optically and correlated with texture, mineral habit, and shading on the photomicrographs in Appendix II, Part 2. Mineral proportions were then determined by counting the minerals present at intersections of a five mm mylar grid over the photomicrographs. The data are tabulated in Appendix II, Part 3, Table 1 and presented graphically in figs. 6 through 12. Preferred orientation and/or nonuniform distribution of minerals in a rock may introduce significant bias in modal analyses as shown in figs. 13 and 14. Field mapping has indicated that both features are present in the rocks of the South Kawishiwi intrusion. Nonuniform distribution of minerals is produced by segregation of olivine and plagioclase-rich layers (modal layering), which from the geologic mapping appears to be sporadically developed beyond about 3 km southeast of the basal contact. Preferred orientation of plagioclase defines the foliation in the troctolitic-gabbroic series rocks and is present throughout the South Kawishiwi intrusion (note the distribution of foliation symbols on the accompanying map of the bedrock geology). Modal

analyses of randomly oriented and selected samples of rocks with preferred orientation and modal layering should show a dispersion of any systematic variations as indicated in figs. 13 and 14. The modal data on olivine, plagioclase and to a lesser extent clinopyroxene, exhibit this behavior (figs. 6, 7 and 8). The fanning of the scatter in the data with distance from the contact indicates that preferred orientation and/or modal layering of these minerals increases away from the contact. The change appears to be gradual rather than discontinuous.

The modal data for orthopyroxene, opaques and biotite show a distinctly different distribution with distance from the contact (figs. 9, 10 and 11). The data on these minerals on the modal percent vs distance plots are scattered over areas which have an upper bound which fits an exponential decrease in the abundance of each of the minerals with distance from the contact. Biotite, which is readily recognizable in the microscope and photomicrographs because of a distinctive color and habit, shows the least scatter in the modal data. The opaque minerals (iron-titanium oxides and sulfides) and orthopyroxene show a somewhat larger scatter than biotite, but the overall abundance of these minerals definitely decreases exponentially with distance from the contact.

3) Mineral Chemistry

It has been shown experimentially that the Mg/Mg + Fe ratio of olivines reflects the Fe-Mg composition of the melt from which olivine crystallizes and that the distribution coefficient for Fe and Mg between melt and crystal is independent of the overall bulk composition, the oxidation state or temperature of crystallization of the melt (Roeder and Emslie, 1970; Walker et al., 1976). There may be some pressure dependence of the distribution coefficient for melts containing water (Mysen, 1976). Thus one can infer the Mg/Mg + Fe ratio of the bulk melt from which a rock crystallized from the composition of olivine in the rock. The calcium content of olivine has been shown to reflect either the depth or rate of cooling (Mudrey, 1973). In view of these petrogenetic relationships for olivine compositions, this mineral was selected for new analyses to provide insights into the problem of the original magma composition and conditions of crystallization of the troctolitic-gabbroic series rocks.

Seventy-five electron microprobe analyses were completed on samples from the South Kawishiwi intrusion. Variations in manganese content of olivine follow those for iron, nickel variations parallel those of magnesium, and silica content provides a check on the stoichiometry of the analyses. Therefore analyses were made for those elements as well as Mg, Fe and Ca. The data are compiled in Appendix II, Part 3, Table 3 and the variations in the Mg/Mg + Fe ratio of olivine with distance from the contact is shown in fig. 15. The variation in compositions of olivine appears to show as wide a

variation within single samples (8 mole percent) as is found across a 3.5 km interval away from the contact (12 mole percent). This variation is similar to that previously reported for a variety of rocks from the troctolitic-gabbroic series (Appendix 1, p. 7) and shows no regular variations with distance from the contact over the distance determined.

m. Results of logging of drill core.

Eighteen drill holes from the southwestern part of the map area were selected for detailed logging for this report. The specific holes were chosen to provide data on the bedrock geology of a covered area, and to make a preliminary evaluation of the potential significance of fracture data from drill core material. The results of the logging are presented in computer coded form in Appendix III, Part 1. The card deck for the data is available from the Minnesota Geological Survey.

The fracture data were categorized with regard to inclinations and nature of the fracture: open— core physically separated, closed— fracture visible but core not separated, filled— hydrous minerals or sulfides along fracture, unfilled— no secondary mineralization along fractures. The number of fractures of these various types per ten-foot interval were counted and recorded (Appendix III, Part 1).

Logging of rock types was done visually with the aid of a hand lens using the hand specimen characteristics of minerals recognized by James Sullivan (personal communication) of the Department of Natural Resources. Mineral proportions used to define rock types and grain size variations were visually estimated. The stratigraphy of the holes and percentages of rock types recognized are summarized in Appendix III, Part 2.

The variation of total fractures with depth is presented graphically and in tabular form for each hole in Appendix III, Part 3. These plots show that there is a strong positive correlation (.86) of total fractures with depth for the shallow hole A3-3 (110 ft. deep); a significant negative correlation (-.64) for IC32718 which is 720 feet deep. The overall variation of the correlation of total number of fractures with total depth is shown in fig. 16. In homogeneous, isotropic material the normal expectation is a decrease in fractures with depth. This is clearly not the case with most of the drill holes studied. Changes in rock types, grain size, or the intersection of a fault zone could reverse the expected trend. A suggestion that these factors are important is provided by a preliminary analysis of the drill core data in terms of fracture density (fractures per foot) for different rock types. Plots of these data indicate that troctolitic coarse-grained rocks have a higher overall fracture density than fine-grained hornfels (figs. 17 and 18). Mineralized rocks irrespective of rock type or grain size also have a relatively high fracture density (fig. 19)

C. Structure

Data on three different structural elements are presented on the accompanying map of the bedrock geology: 1) Planar features, 2) Faults, and 3) the configuration of the basal contact.

1. Planar features

a. Foliation

As discussed in the description of rock units, foliation in Duluth Complex rocks is defined by planar orientation of tabular minerals (Appendix 1, p. 3). It is a record in the rocks of the process of gravity segregation of individual mineral grains from melt during crystallization of a magma. The foliation of the Bald Eagle intrusion is of the flow type (Weiblen, 1965) and the foliation in the South Kawishiwi intrusion is believed to be largely due to gravity segregation (Appendix I, p. 12).

b. Mineral layering

Flow or gravity segregation of minerals from melt during crystallization also produces layering in gabbroic rocks (fig. 23). This layering may occur on various scales. For example, large scale segregation may produce mappable units with stratigraphic contacts and internal layering as discussed in the section on map units. Meter to centimeter scale segregation produces recognizable layering similar to bedding in sedimentary rocks. This small scale layering has been referred to as mineral or modal layering in gabbroic rocks (Appendix 1, p. 3).

In the Duluth Complex the foliation, stratigraphic layering and modal layering have all been found to be generally concordant. In the Bald Eagle intrusion these features define a funnel-shaped intrusion of the form shown in fig. 20. In the rest of the troctolitic-gabbroic series rocks the general orientation of planar features has been considered to be consistent with a gently southeast dipping structure (fig.) (Appendix I, p. 20). Detailed mapping, however, has continually revealed exceptions to this simple interpretation. For example, in the Kawishiwi area in Sec. 35, T.62N., R.11W. the foliation has a north-northeast strike which is at a high angle to the contact, and in Sec. 7, T.61N., R.10W. the foliation dips to the west rather than southeast. Data such as these have suggested that the present orientation of planar features in the troctolitic-gabbroic series rocks may be fault controlled (Appendix I, p. 20).

2. Faults

Recognition of offset of geological contacts or cataclastic zones which provide evidence for faults has been limited in the Duluth Complex (Appendix I, p. 18). Cooper (1975) noted that spacing between joints decreases toward linear topographic lows in the Kawishiwi area which suggests that these lows may be zones of fractured rock (cataclastic zones) which were preferentially removed during glaciation. Such linear

cataclastic zones are characteristic of faults but do not prove their actual presence. Three types of faults are drawn on the map of the bedrock geology: 1) Known faults-- those mapped in the Lower and Middle Precambrian on the basis of offset of geologic units and/or linear cataclastic zones, 2) faults inferred from apparent offsets of geologic units in the Duluth Complex, and 3) faults inferred on the basis of coincidence of topographic and aeromagnetic lineaments, and disrupted trends of contacts between and/or foliations within mapped units. The last type is referred to as faults inferred from geophysical data on the map of the bedrock geology.

The Kawishiwi area is characterized by a set of faults trending N.10E. to N.30E. that cut both troctolitic-gabbroic series rocks and offset the basal contact along the eastern boundary of the South Kawishiwi intrusion.

In the Hoyt Lakes—Dunka River area there are two distinct sets of faults: one trending N-S in R.12 and 13W., and the other E-W in R.14W. These may be construed to define a block which offsets the basal contact in a left lateral sense in Secs. 4, 15 and 16, T.59N., R.14W., Sec. 1, T.59N., R.13W.

Inferred faults are conspicuously absent in Secs. 15-36, T.60N.. R.11W. and T.59N., R.11W. Whether this is due to a fortuitous lack of surface expression or whether it represents a distinct block separating the Kawishiwi and Hoyt Lakes--Dunka River areas is not clear. Based on the inferred faults it appears that the northeast trending contacts of the Bald Eagle intrusion are probably not fault contacts.

The lineament trends south of the area of extensive exposures of the Duluth Complex reflect glacial features (Toimi drumlin field). Their rather consistent N.45E. trend is distinct from the lineament and inferred fault trends to the north. This raises the interesting question of whether the trend of the glacial features reflects bedrock trends in a distinct structural block or whether it is strictly controlled by glacial processes.

3. The configuration of the basal contact of the Duluth Complex.

Previous mapping defined the surface expression of the basal contact of the Duluth Complex in the Hoyt Lakes—Kawishiwi area as a northeast trending, arcuate feature with local continuous inflections (Appendix I, p. 5). The new data on inferred faults discussed above implies that the basal contact is locally offset by faults and therefore is characterized by a series of discontinuous inflections. The question of whether these represent a trace of the lower surface along which the magma for the troctolitic-gabbroic series rocks was emplaced or later offsets of these rocks is discussed in the section on interpretation below.

II. Interpretative Geology

The new structural and petrologic data on the Duluth Complex acquired in the preparation of this report provide the basis for profoundly new interpretations of several aspects of the Complex in the Hoyt Lakes--Kawishiwi area. These include: A) The overall structure of the Complex. B) Size, shape and mode of emplacement

of individual intrusions. C) The distribution of sulfide mineralization.

A. The overall structure of the Complex in the Hoyt Lakes—Kawishiwi area.

The results of the lineament studies discussed in the accompanying report on lineament analysis add further evidence for the presence of a well-developed set of northeast trending and a less well-developed set of northwest trending faults in the Hoyt Lakes--Kawishiwi area. The northeast trend is the direction along which deep crustal fracturing occurred on a total of 50-70 km. of crustal extension which had developed during the emplacement of the Duluth Complex and other Keweenawan rocks in the Midcontinental Rift (see references in Appendix I, p. 18). The trend is reflected by the overall trend of the rift, a Keweenawan dike swarm southwest of Duluth (Wright et al., 1970), the basal contact of the Duluth Complex between Duluth and Hoyt Lakes, as well as by the northeast trending inferred faults in the Hoyt Lakes--Kawishiwi area. The northwest trend is the direction along which segments of the rift are offset (transform direction), and parallel to which the Keweenawan crustal extension occurred (Chase and Gilmer, 1973).

The coincidence of the inferred faults in the Hoyt Lakes—Kawishiwi area with the major crustal fracture pattern associated with the Midcontinent Rift suggests that the inferred faults may have been produced by propagation of the deep crustal fracture pattern into the Duluth Complex rocks. These relationships lend further support to the structural model for the Duluth Complex proposed by Weiblen and Morey (1975) (Appendix I, p. 20-23) who suggested that foundering of crustal blocks as indicated in Appendix I, fig. 12, p. 21 produced the overall void space for the Duluth Complex rocks. As indicated in fig. 20 this model provides a rational explanation for the trend of the basal contact of the Duluth Complex between Duluth and Hoyt Lakes. It also suggests that any layering or succession of rock types could best be viewed in cross sections normal to this contact.

Up to now there has been no explicit model for the contact zone in the Hoyt Lakes—Kawishiwi area. However, as shown in fig. 21 the new structural data presented in this report suggest that the complexity of this segment of the basal contact of the Duluth Complex may result from the intersection of the northeast-northwest fault system of the Midcontinent Rift with another regional structural feature: the unconformity between the Lower and Middle Precambrian.

B. Shape, size and mode of emplacement of the troctolitic-gabbroic rocks.

Except for the Bald Eagle intrusion, the troctolitic-gabbroic rocks were considered in the past to have been flat-lying, sheet-like structures which now dip toward Lake Superior due to subsidence associated with the formation of the Lake Superior syncline in Late Keweenawan time (Appendix I, p. 20). The data discussed in the previous section imply that the original geometry was probably much more complex (fig. 22).

In the Kawishiwi area the new structural data are consistent with the old interpretation that the Bald Eagle intrusion could be a feeder for the South Kawishiwi intrusion (Weiblen, 1965). With the new interpretation that the geophysical anomalies southwest of the present exposures of the Bald Eagle intrusion represent an extension of its flow-layered rocks, we may view the

troctolitic-gabbroic rocks of the Kawishiwi area to be all part of one fault bounded, genetically related sequence which changes from flow layered rocks of a feeder zone on the east to gravity layered rocks of a faulted, east-dipping sheet-like mass on the west (fig. 23).

The new petrologic data obtained in the Minnesota Highway 1 traverse and discussed above support the view that all the troctolitic-gabbroic rocks in the Kawishiwi area are genetically related. The new data also shed light on the three-dimensional shape of the intrusive mass proposed above. First of all the gradual increase in grain size of plagioclase (fig. 5) away from the basal contact is consistent with the assumption that all the rocks along the traverse are genetically related. The grain size data may be interpreted to represent a gradual decrease in cooling rate with distance away from the contact for a single intrusive volume of magma. This implies a roughly continuous increase in depth to a cooling surface (i.e., the basal contact) over the 10 km. distance of the traverse. Secondly, the fanning of the data on plots of olivine (fig. 6), plagioclase (fig. 7), and to a lesser extent clinopyroxene (fig. 8) versus distance from the contact imply a gradual increase in the gravity-layered nature of the rocks. This in turn implies a gradual increase in thickness of an intrusive mass away from the contact since the process of gravity-segregation would be more efficient in larger, slower-cooling volumes of magma. Based on these interpretations it is possible to propose the general shape and size shown in fig. 24 for the intrusive mass of troctolitic-gabbroic rocks in the Kawishiwi area.

The formation and filling of a magma chamber such as that proposed in fig. 24 would necessarily be a complex process. As discussed below the processes which would take place in the contact or border zone of the chamber would be particularly complex. Away from the contact (0.5-1 km.) the grain size and modal data (figs. 5-11) discussed above are not inconsistent with the view that the troctolitic-gabbroic rocks in the Kawishiwi area all crystallized from a single volume of magma, that is, that chambers formed and filled completely before significant solidification occurred. The alternative view, that smaller volumes of unspecified size had local feeders from depth and were emplaced and solidified successively, seems less likely since this would require a regular increase in chamber size away from the basal contact to produce the observed variations in size and mineral layering. The geometric and genetic relationship of the troctolitic-gabbroic rocks in the Kawishiwi and Hoyt Lakes area has always been problematical (Appendix I, p. 13) Based on the slight change of trend and the spacing of the northeast trending faults in the two areas, it is conceivable that they represent two distinct intrusive masses of slightly different shape, size, and mode of emplacement. Hopefully the petrologic data from the Hoyt Lakes area traverse will shed light on this problem.

C. Distribution of sulfide mineralization in the Hoyt Lakes—Kawishwi area.

Past geologic mapping and the reported data from the drilling and exploration programs of mining companies have indicated that the economically interesting sulfide mineralization in the Hoyt Lakes—Kawishiwi area is restricted to a zone within about 0.5 km. of the basal contact (Bonnichsen, 1972). Assay data from drill core would be needed to characterize the lateral variations in thickness and grade of the mineralized zone.

It is interesting to note that on the data base map of the Hoyt Lakes—Kawishiwi area the drill holes lie along northeast trending lines within the

contact zone. If this present pattern of drilling is in any way representative of the distribution of economically interesting grades of mineralization, it would appear that there is a strong correlation of sulfide mineralization with the northeast-trending inferred fault system shown on the map of the bedrock geology.

The INCO mine site and Maturi shaft are located to the southwest of a major inflection in the basal contact of the South Kawishiwi intrusion (see accompanying map of the bedrock geology). This configuration is repeated in the Hoyt Lakes area by the location of the AMAX shaft and the U.S. Steel sample site. These relationships are shown schematically in fig. 25, and they suggest that a systematic variation in thickness, grade or texture of the sulfide mineralization may exist normal to the northeast-trending inferred faults in the contact zone. From the surface outcrops there are a greater number of inclusions and the irregularity in textures is more pronounced in the vicinity of the INCO Spruce Road mine site than around the Maturi shaft. This suggests that complex faulting of country rock and movement during crystallization was more intense in the Spruce Road mine site area than at the Maturi shaft. These would be the expected relationships for movement of fault blocks with the configuration shown in fig. 25. Possibly these relationships are repeated in the Hoyt Lakes area.

The exponential decrease in orthopyroxene, opaque minerals and biotite, away from the basal contact of the troctolitic-gabbroic rocks in the Kawishiwi area (figs. 9 to 11) can be interpreted as a record of the distribution of the products of diffusion-controlled reactions (Table 2). These involved diffusion of water and potassium for biotite, oxygen and sulfur for the opaque minerals (iron-titantium oxides and sulfides), and silica for orthopyroxene. This interpretation is consistent with and provides additional evidence for the model of sulfide mineralization in the Duluth Complex proposed by Weiblen and Morey (1976) (Appendix IV).

Although the drill core data on the depth and thickness of zones with visible sulfides listed in Appendix III are limited, they may be used to infer some general characteristics of the mineralization in the largely covered area south of Hoyt Lakes. Preliminary examination of plots of fracture density versus depth suggests: 1) More holes are mineralized within 300 feet of the surface and between about 450 and 750 feet at depth than at other depth intervals (fig. 26); 2) Observed hornfels are restricted to an interval between about 200 to 550 feet and 1250 to 1350 feet (fig. 27); 3) Visible sulfide occurrences are not as abundant in the hornfels as in the enclosing troctolitic-gabbroic rocks (figs. 27 and 28); and 4) The maximum number of fractures in ten-foot intervals of hornfels (48 at depths less than 560 feet and 85 at 1290 feet) is much lower than the maximum in mineralized troctolite (122) (Appendix III, Part 5)

III. Recommendations

A new basis for placing geologic constraints on a number of problems related to the evaluation and potential development of copper-nickel resources in the area is provided by the compilation of geologic data, the new inferences with regard to correlation of rock units and structural relations depicted on the bedrock map of the Hoyt Lakes--Kawishiwi area, and the data and interpretations presented in this report. New constraints may be placed on: A. Ore estimation; B. Mining methods; C. Exploration; and D. Environmental monitoring. Although the geologic data

referenced and included in this report might appear at first sight to be voluminous, they are, in fact, quite minimal in view of the extensive area they cover. In view of this it should be emphasized that any constraints drawn from the present data base and its interpretation must be continually and seriously scrutinized in light of new data.

A. Ore estimation

Data in this report suggest two new geologic constraints that may be placed on any method of ore estimation:

1. The inferred fault system depicted on the map of the bedrock geology and the interpretation of the surface distribution of sulfide mineralization along the contact suggest that the faults might be realistic dividers for lateral extrapolation and averaging of drill core data.

2. If the interpretive model for the origin of the sulfides presented here (Appendix IV) is correct, the assay data should show the same exponential decrease with distance from the contact (and perhaps at the border of mineralized intersections in drill core) shown by the surface extent of minerals associated with mineralization (figs. 9 to 11). Thus an exponential function might be used to define the borders of mineralized zones (fig. 28).

B. Mining methods.

The limited data on interpretation of fractures presented in this report (Appendix III) indicate that local environments more favorable for mining than others may exist in the mineralized zone. For example, the occurrence of relatively unfractured hornfels (fig. 27) overlying highly fractured mineralized zones (fig. 26) would provide the relatively ideal circumstances of strong roof rocks for a mineralized zone which could be mined with less expense and energy consumption than an unfractured ore zone which might underlie near-surface highly fractured rocks.

C. Exploration

The possible correlation suggested in this report of sulfide mineralization with the northeast-trending faults and offsets in the contact provides a new insight into controls on localization of ore zones which should aid the continuing search for the elusive occurrences of local, high-grade sulfide mineralization in the contact zone. The present data and the interpretations presented in this report emphasize that reevaluation of surface exposures, lineament analyses, and reinterpretation of geophysical data are needed to pinpoint new target areas for drilling within the contact zone. Because the currently available aeromagnetic data do not provide complete overlap for the Hoyt Lakes—Kawishiwi area, a new aeromagnetic map should be of highest priority in any future research in the area.

D. Environmental monitoring

The inferred fault system in the Hoyt Lakes—Kawishiwi area as depicted on the map of the bedrock geology provides a first cut at evaluating bedrock

control on ground-water circulation in the area. The general fault trends provide a basis for locating faults on a smaller scale in specific locations.

The data on the distribution of hydrous minerals which occur along fractures in the troctolitic-gabbroic rocks (Appendix III) emphasizes the ubiquitous minor occurrence of potentially health hazardous minerals in the area. In a total of 15,894 feet of core logged, 26,424 fractures were observed. Most of these are lined by a zone of hydrous minerals 1-5 mm. wide. This indicates an average abundance of hydrous minerals of about 0.29 percent for all rocks intersected in drill core in the southeastern part of the Hoyt Lakes—Kawishiwi area. This figure may be taken as a rough estimate for the present abundance in exposed surface rocks in the area.

Because almost nothing is known about the hydrous minerals in the Duluth Complex in general, the first task is to begin a program of detailed mineralogic characterization. Other areas that need investigation include:

1) the variety and extent of hydrous minerals associated with sulfide mineralization.

2) the role specific hydrous minerals play in the release of certain elements in the weathering environment.

3) verification of the probable increase in hydrous mineral content of fractured rocks within the linear topographic lows associated with the inferred faults in the Hoyt Lakes—Kawishiwi area.

4) role of hydrous minerals in experimental studies of flotation processes for ore recovery.

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FIGURES

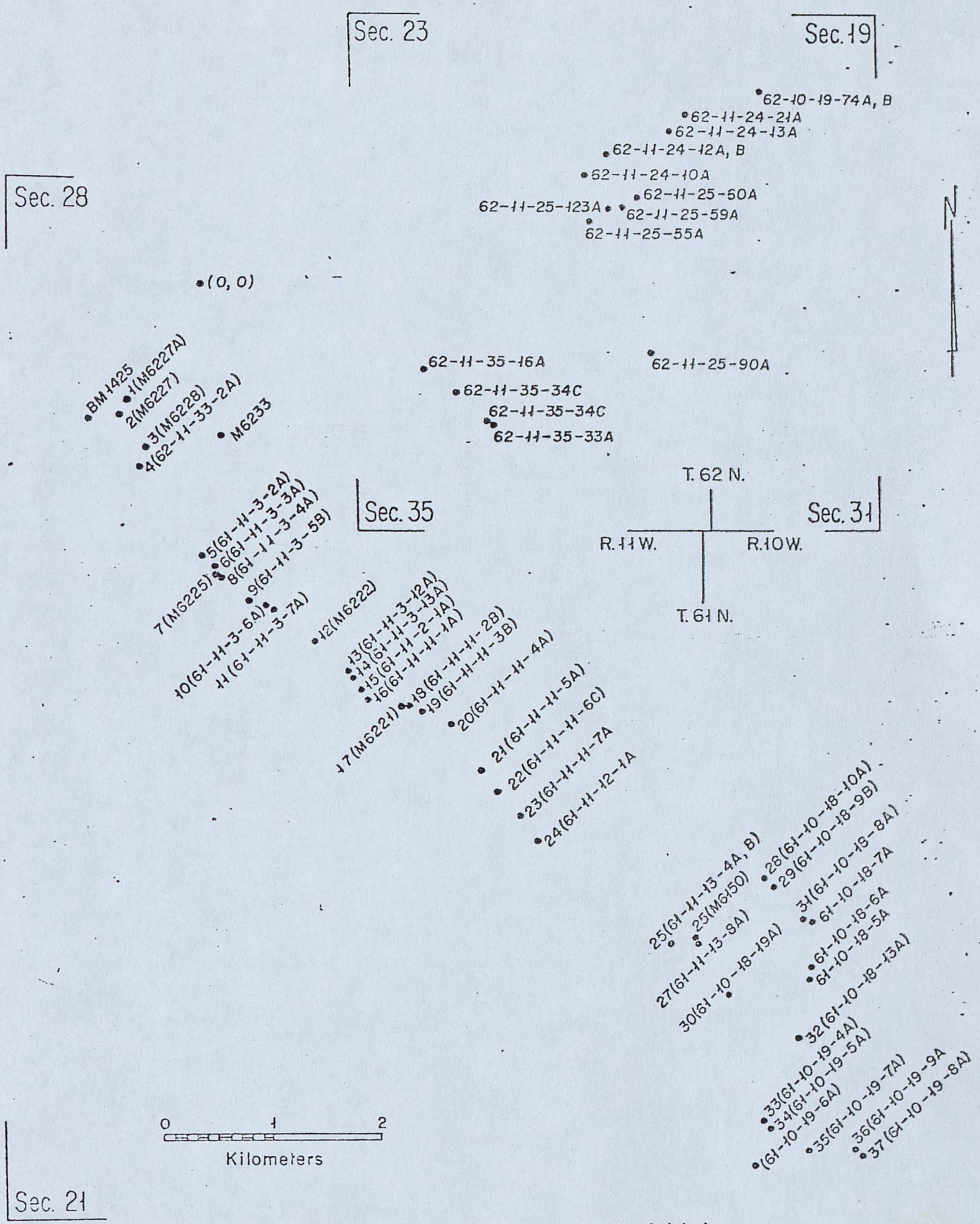


Figure 1. Sample locations of troctolitic rocks in the Kawishiwi area.

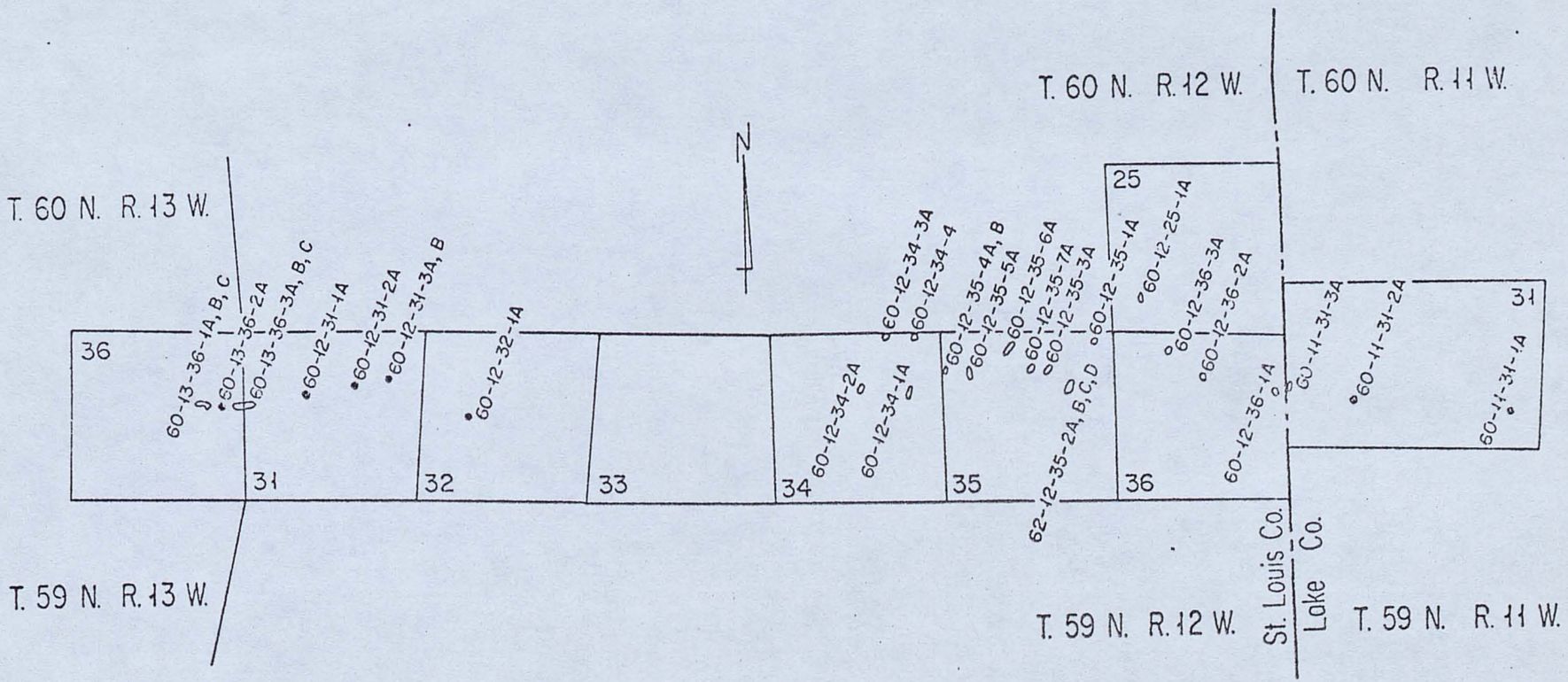


Figure 2. Sample locations of troctolitic-gabbroic rocks in the Hoyt Lakes--Kawishiwi area.

A. Northern traverse.

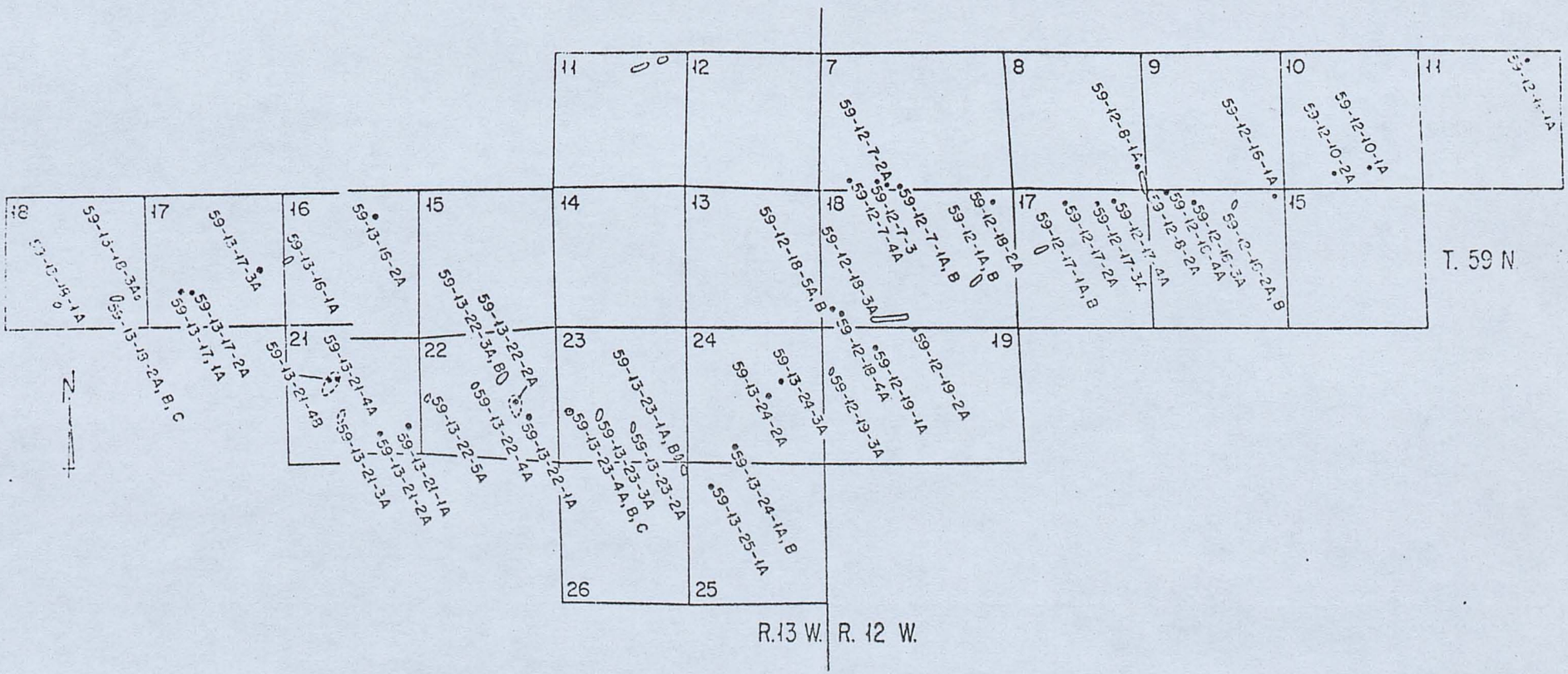


Figure 2. Sample locations of troctolitic-gabbroic rocks in the Hoyt Lakes--Kawishiwi area.
B. Southern traverse.

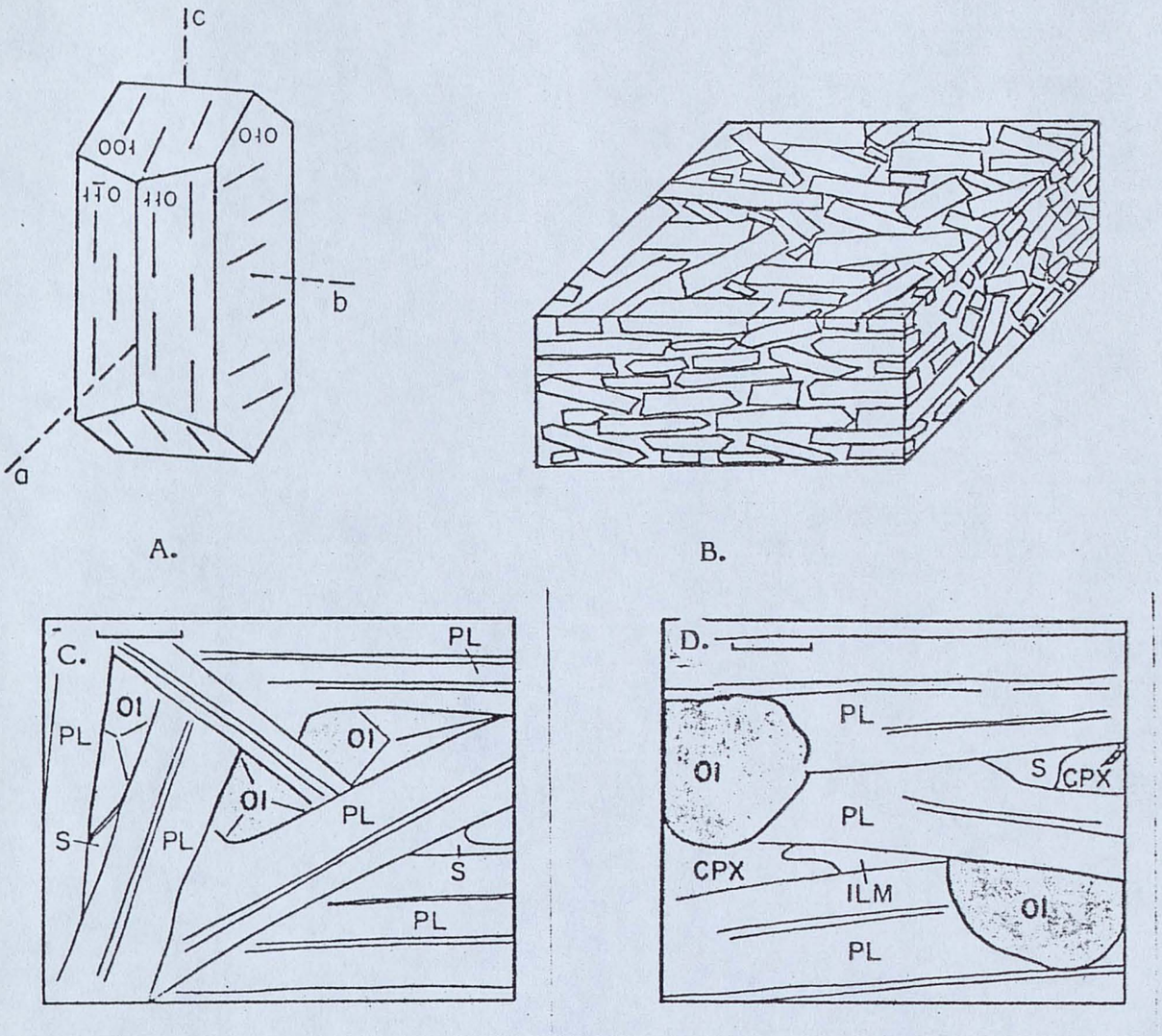


Figure 3. Schematic illustration of the effect of preferred orientation on plagioclase grain size measurements.

A. Schematic diagram of preferred orientation of plagioclase.

B. General shape of tabular plagioclase.

Tabular form of plagioclase (4) indicates that randomly oriented thin sections will show larger differences in length than width. Determination of the different faces (010), (110) and (001) (B) were not made for the width measurements in this study (Appendix II, Part 3, table 1; figs. 4 and 5).

C. In rocks with greater than 80% modal plagioclase, olivine has been found to be interstitial. The best evidence for this relationship is 120° intersections of interstitial olivine grains. The intersection indicates that three olivine grains grew together within a void in the plagioclase framework. The schematic relationships are drawn from textures observed in sample from the Anorthositic Series.

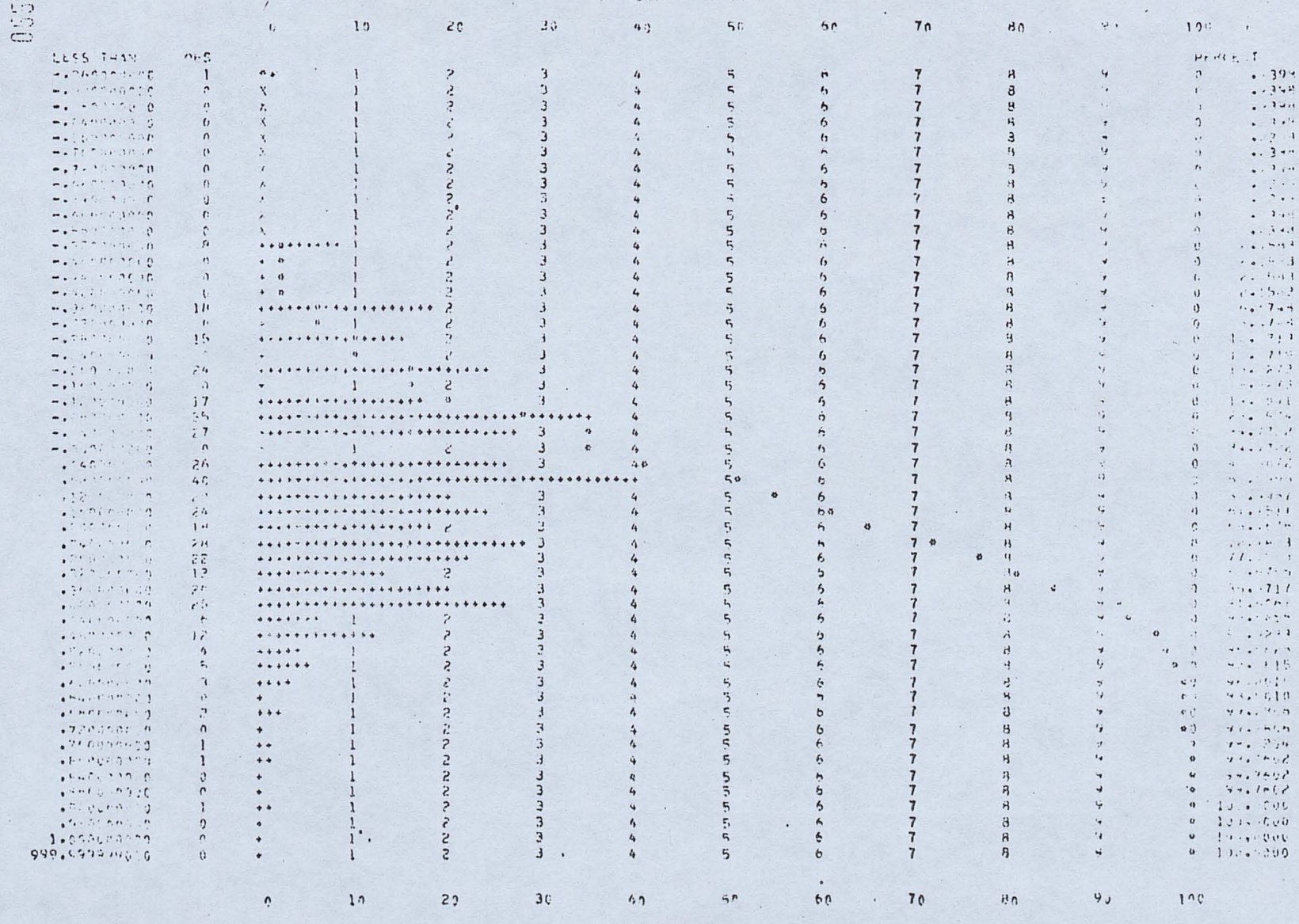
D. In rocks with less than 80% plagioclase, subhedral to extended olivine forms part of the framework along with plagioclase for interstitial pyroxene, ilmenite, sulfide or other late phases in the troctolitic-gabbroic rocks.

055740

PLAGIOCLASE GRAIN SIZE DATA (MM) HAY 1 TRAVERSE

HISTOGRAM OF WIDTH
417 OBSERVATIONS
EACH UNIT = 1 OBSERVATIONS

CUMULATIVE PERCENT



MIN = .100000000 MAX = 7.800070000 MEAN = 1.418744844 S.D. = .8792305549

STATISTICAL PARAMETERS

STD. DEV.= .8802966088 SKEWNESS= 2.044514793 KURTOSIS= 11.476533247

055741

FIGURE 4. HISTOGRAM OF WIDTH OF PLAGIOCLASE GRAINS IN TROCTOLITIC-GABBROIC SERIES ROCKS FROM THE KAWISHIWI AREA.

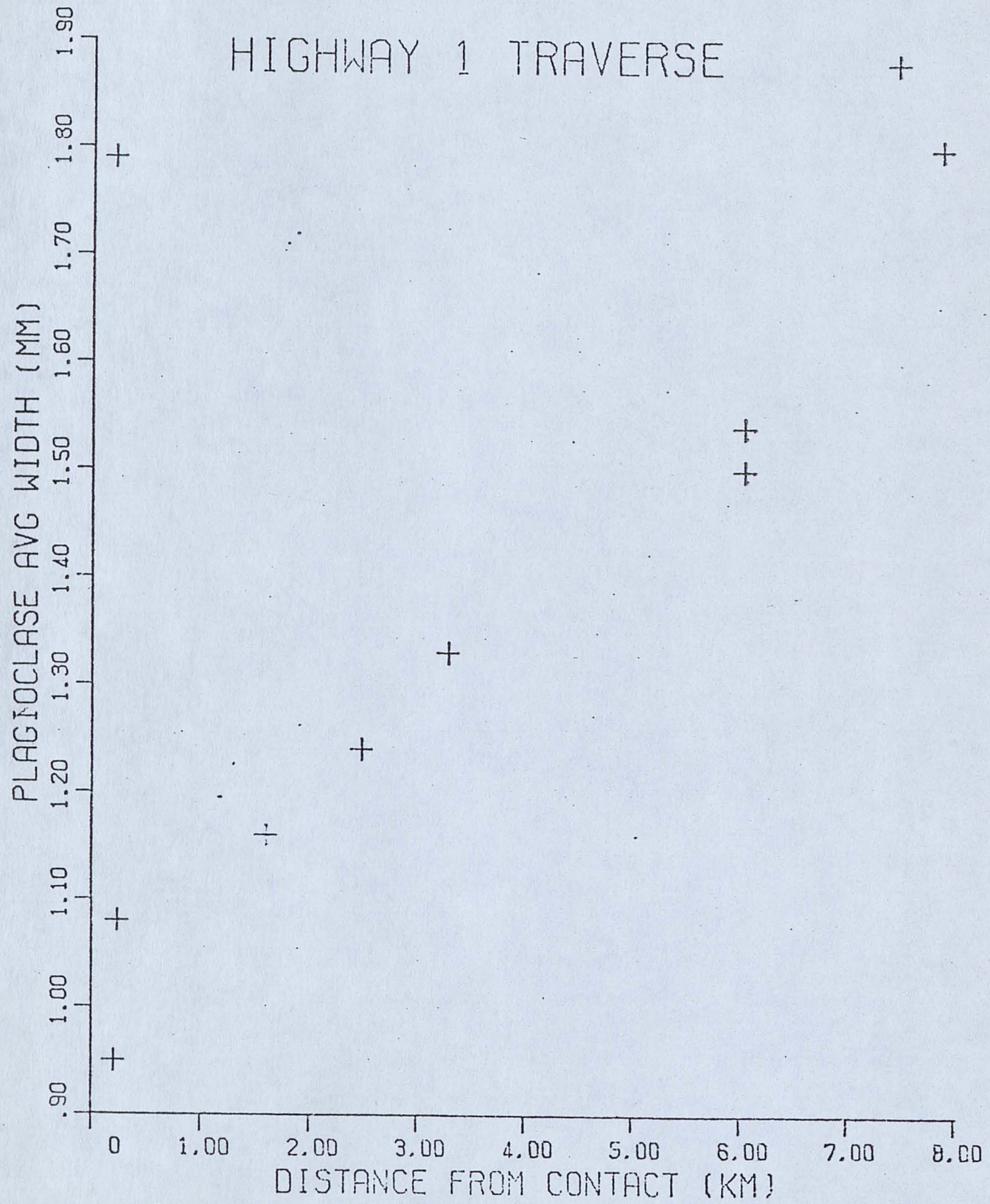


Figure 5. Plot of widths of plagioclase grains versus distance along Minnesota Highway 1 traverse.

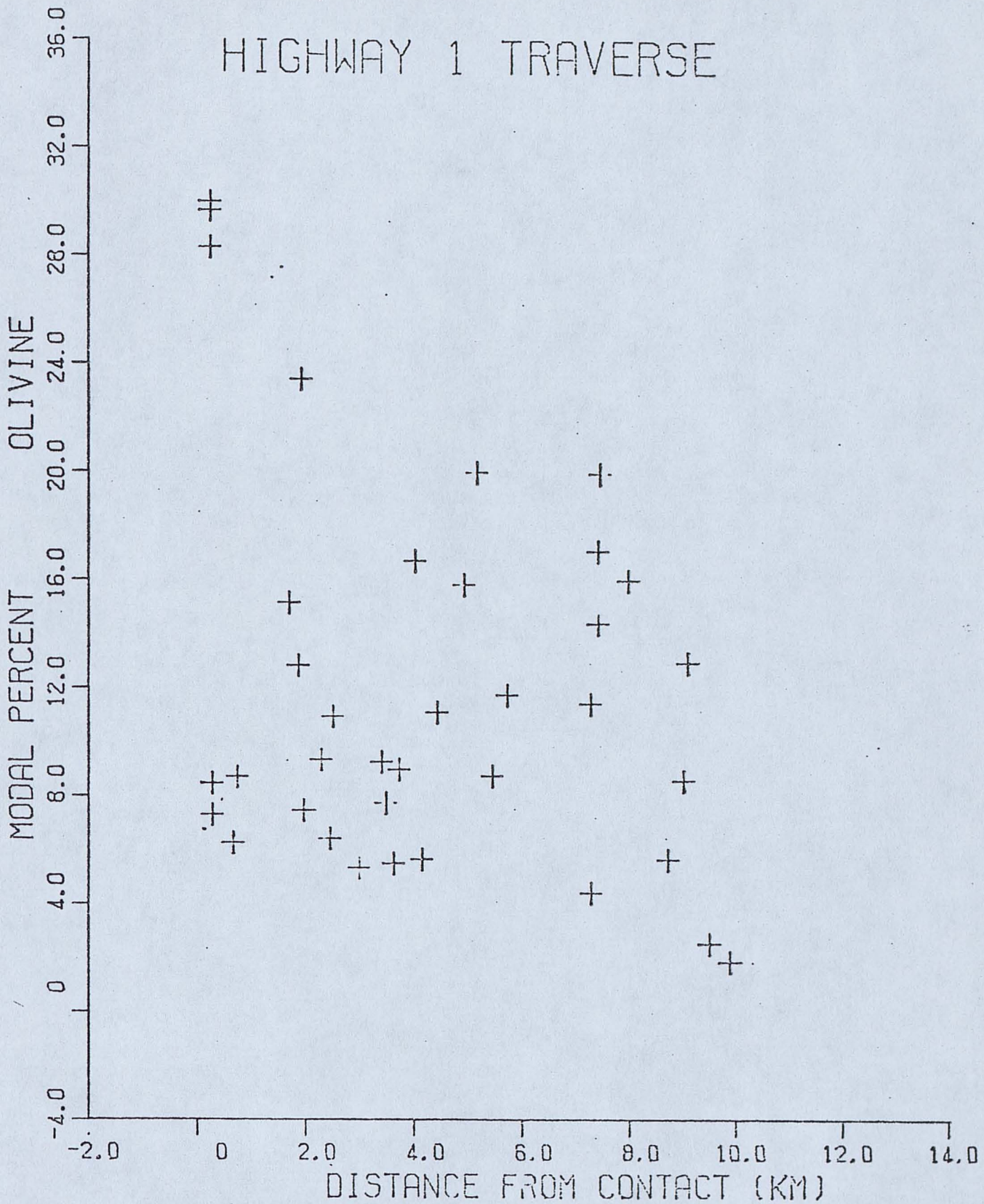


Figure 6. Plot of modal olivine versus distance along Minnesota Highway 1 traverse.

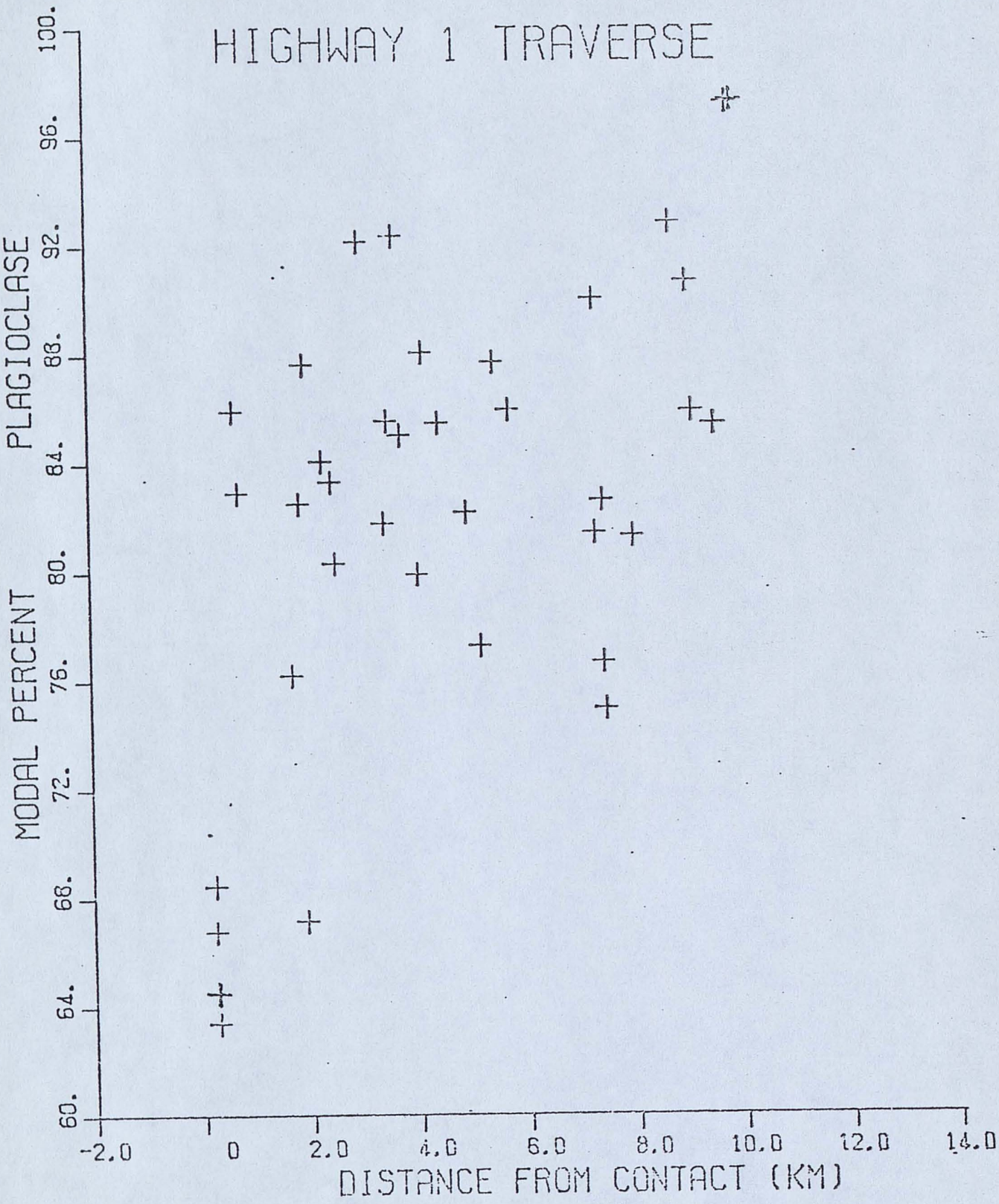


Figure 7. Plot of modal plagioclase versus distance along Minnesota Highway 1 traverse.

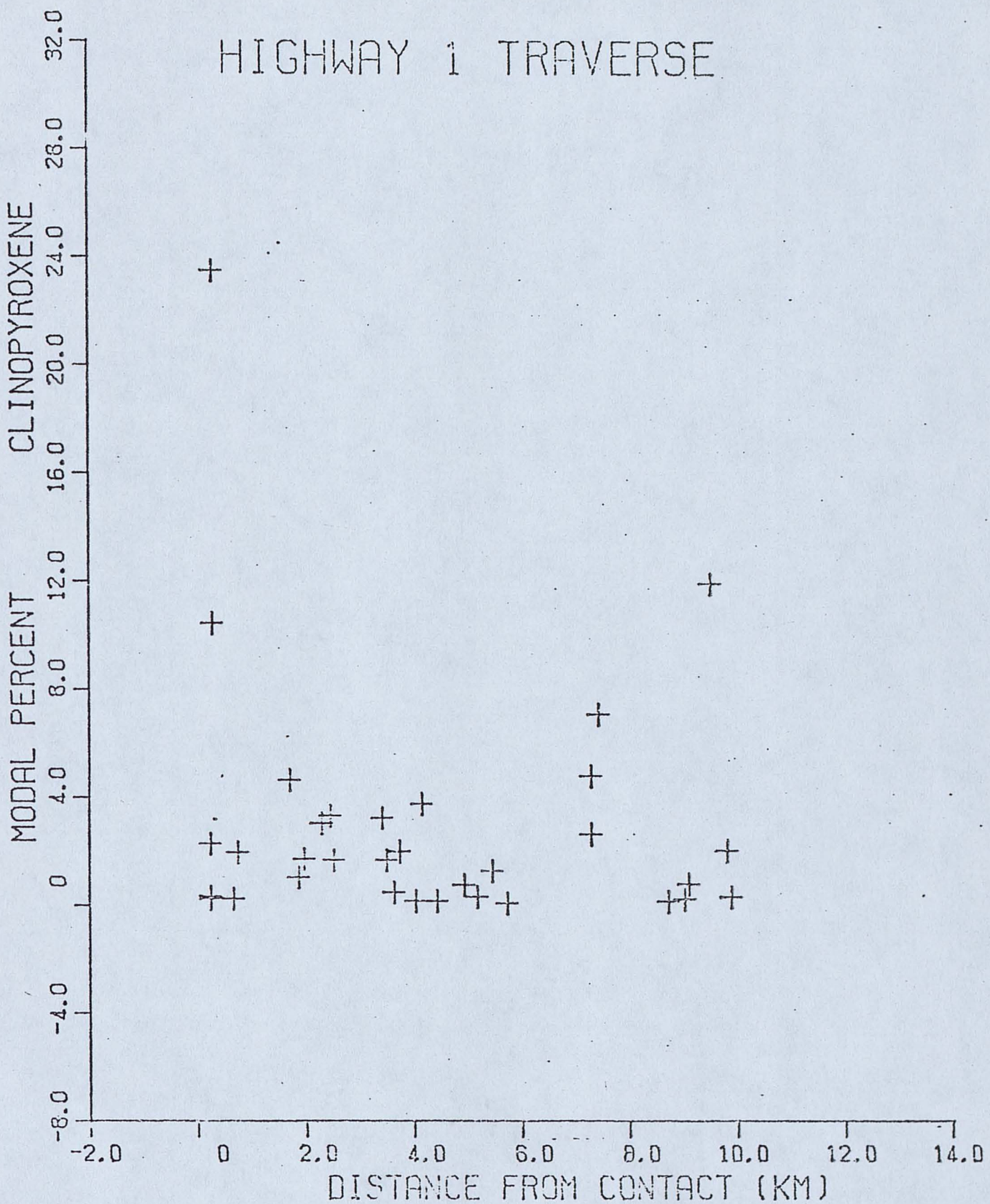


Figure 8. Plot of modal clinopyroxene versus distance along Minnesota Highway 1 traverse.

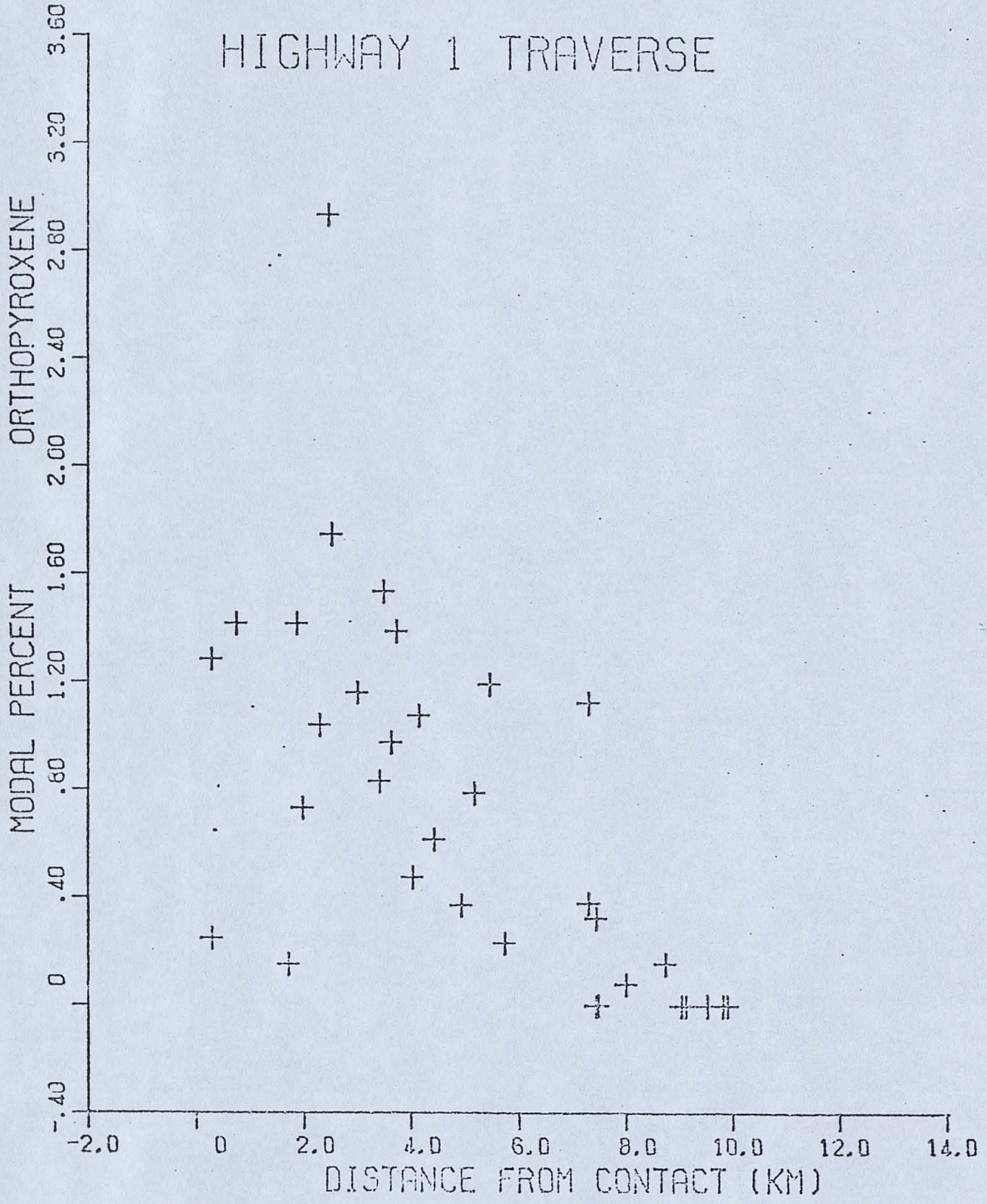


Figure 9. Plot of modal orthopyroxene versus distance along Minnesota Highway 1 traverse.

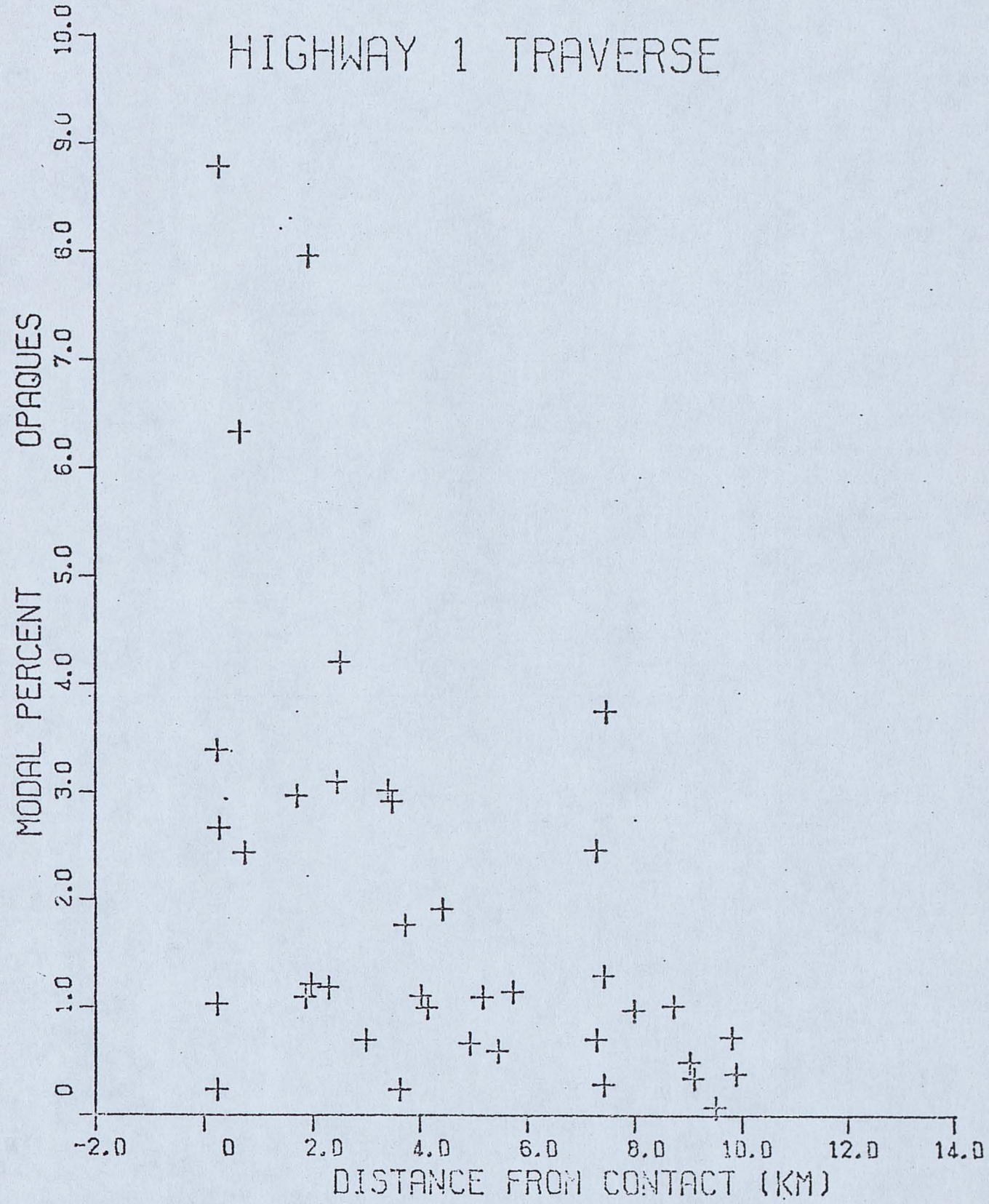


Figure 10. Plot of modal opaque minerals versus distance along Minnesota Highway 1 traverse.

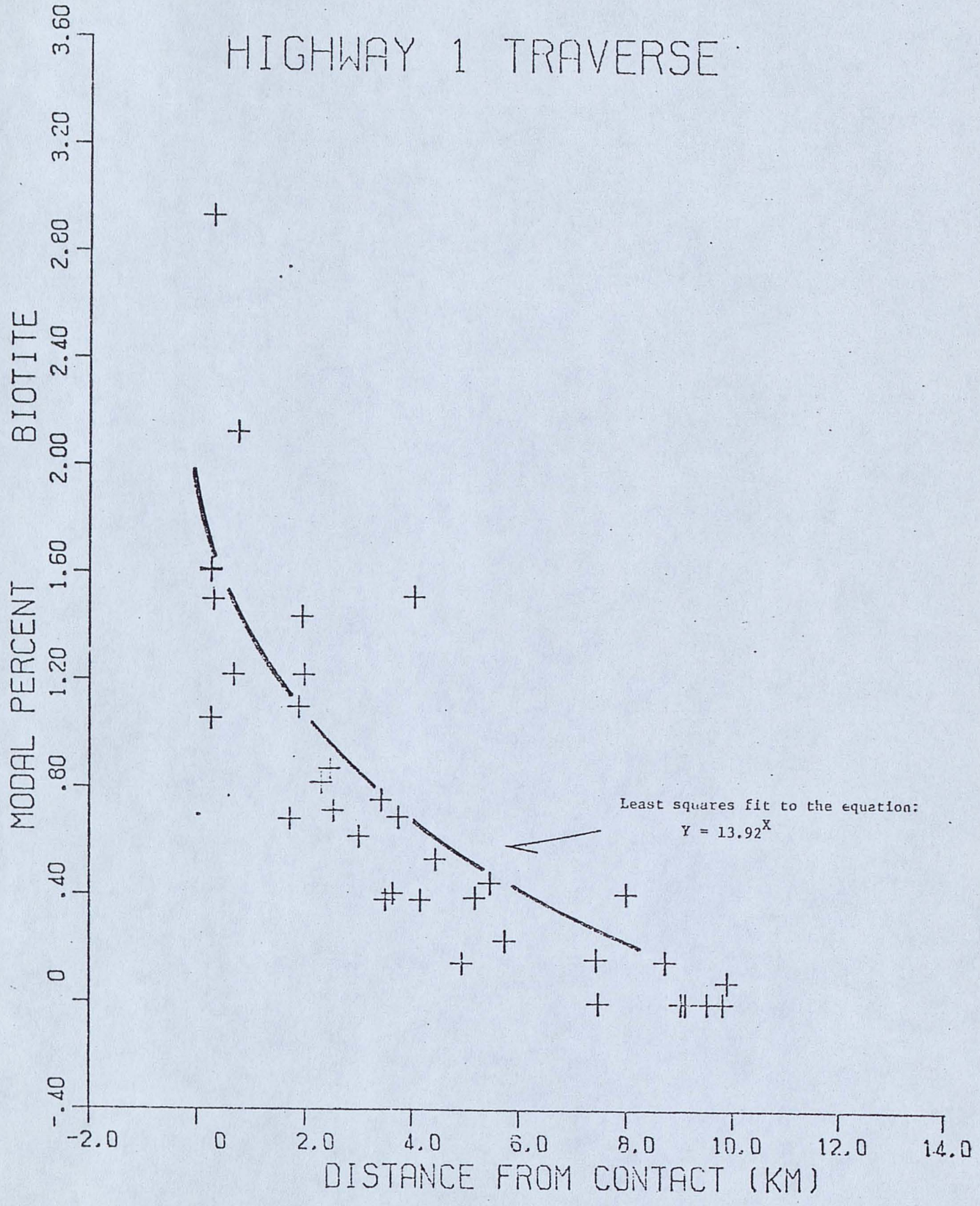


Figure 11. Plot of modal biotite versus distance along Minnesota Highway 1 traverse.

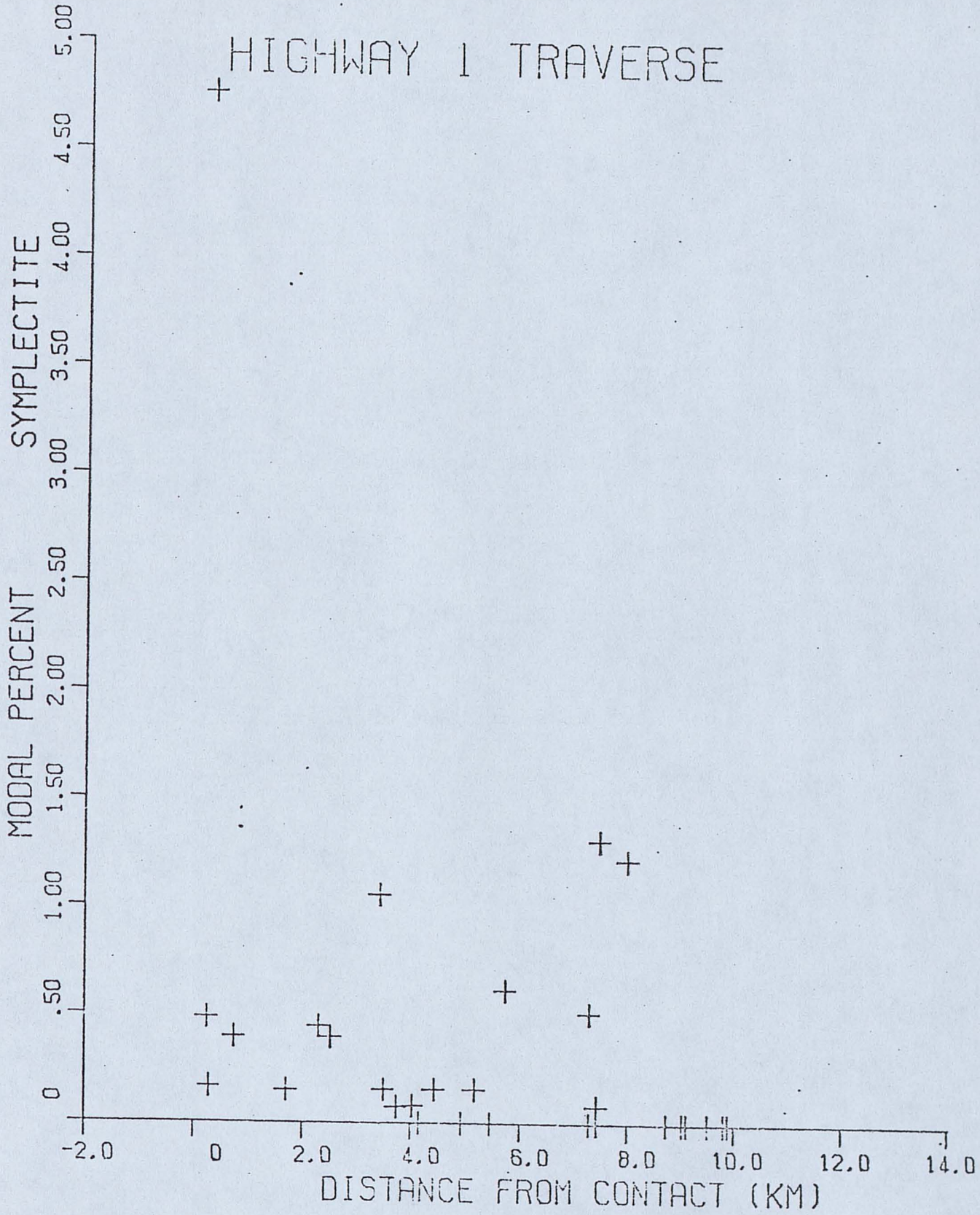


Figure 12. Plot of symplectite versus distance along Minnesota Highway 1 traverse.

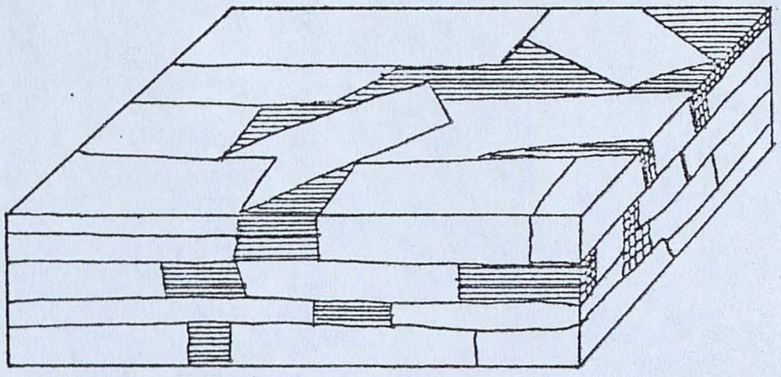


Figure 13. Schematic illustration of the effect of preferred orientation on modal analyses. Thin sections cut normal to the layering shown would indicate a lower percentage of plate-like minerals (black) that occurs interstitially to a tabular mineral like plagioclase.

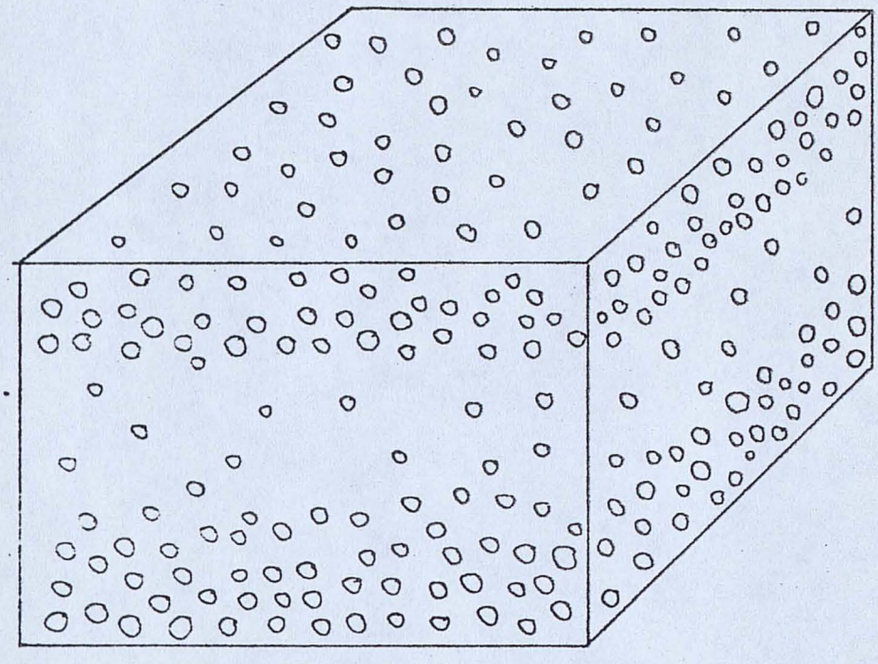


Figure 14. Schematic illustration of the effect of mineral layering on modal analyses. Circles indicate distribution of olivine in layered troctolitic rocks. Randomly cut thin sections would show a wide spread in the amount of olivine. This has been found in samples along the Minnesota Highway 1 traverse (fig. 6).

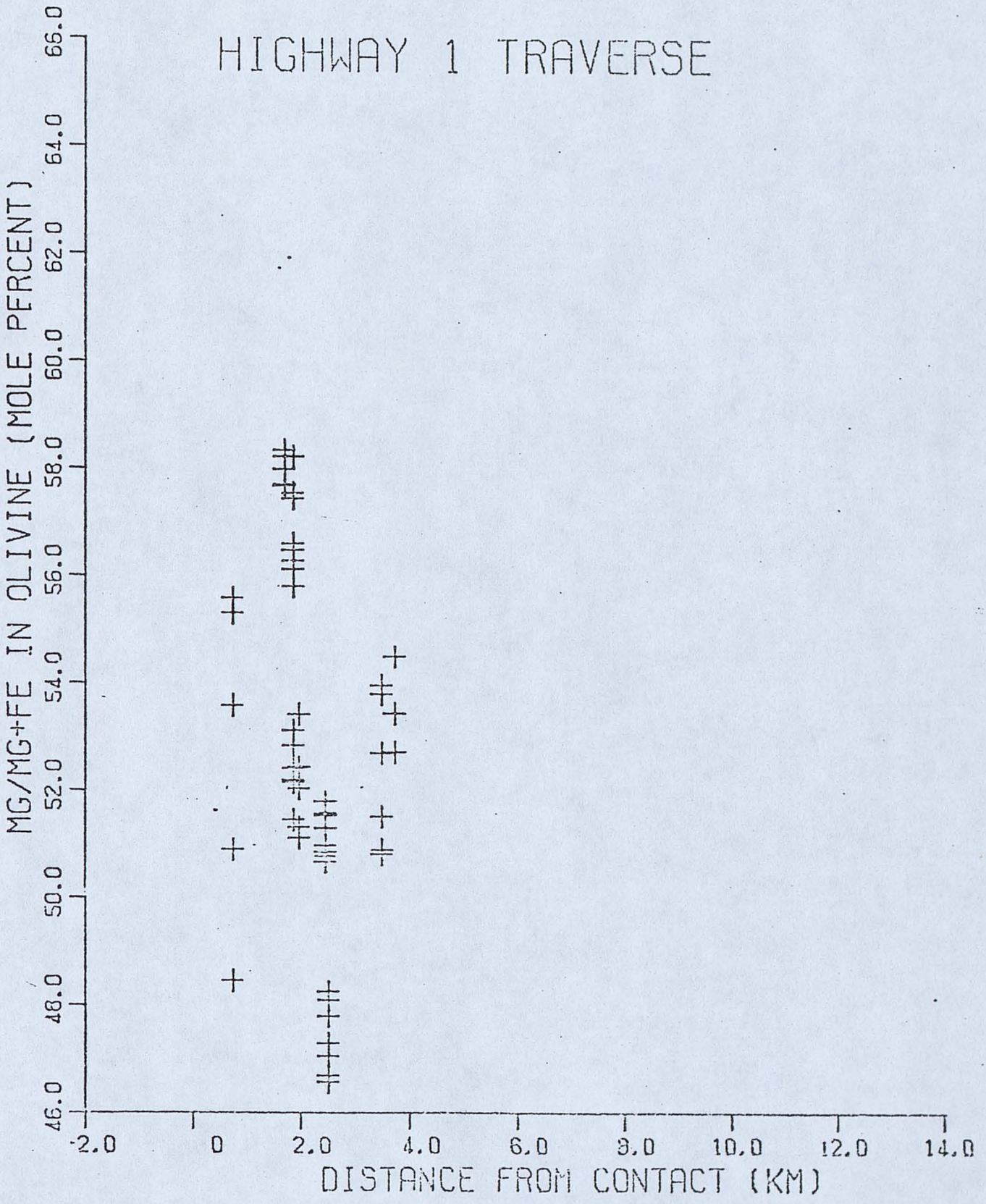


Figure 15. Plot of mole percent Mg/Mg + Fe along Minnesota Highway 1 traverse.

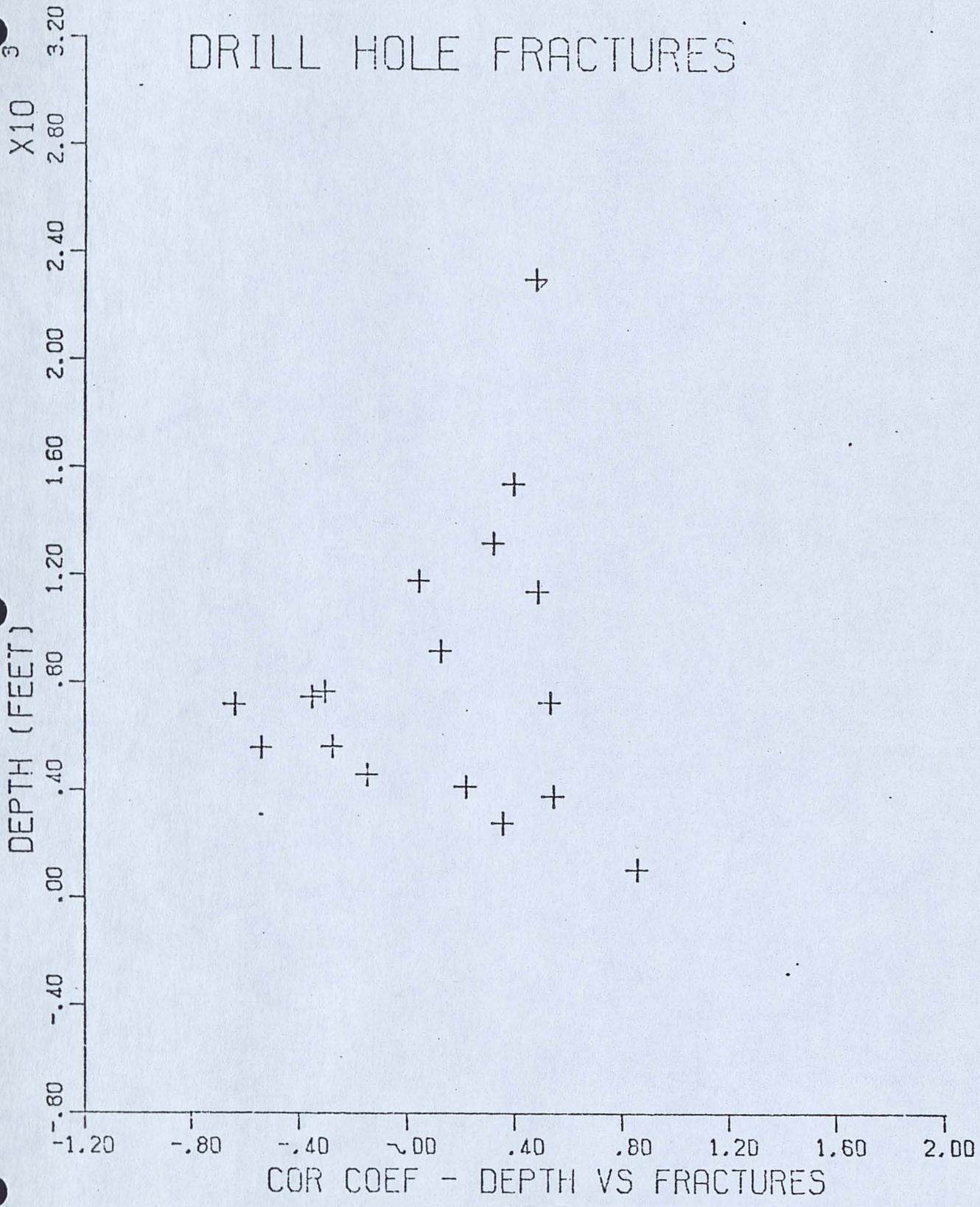


Figure 16. Plot of the variation in correlation coefficients of fracture density with depth versus total depth of drill holes.

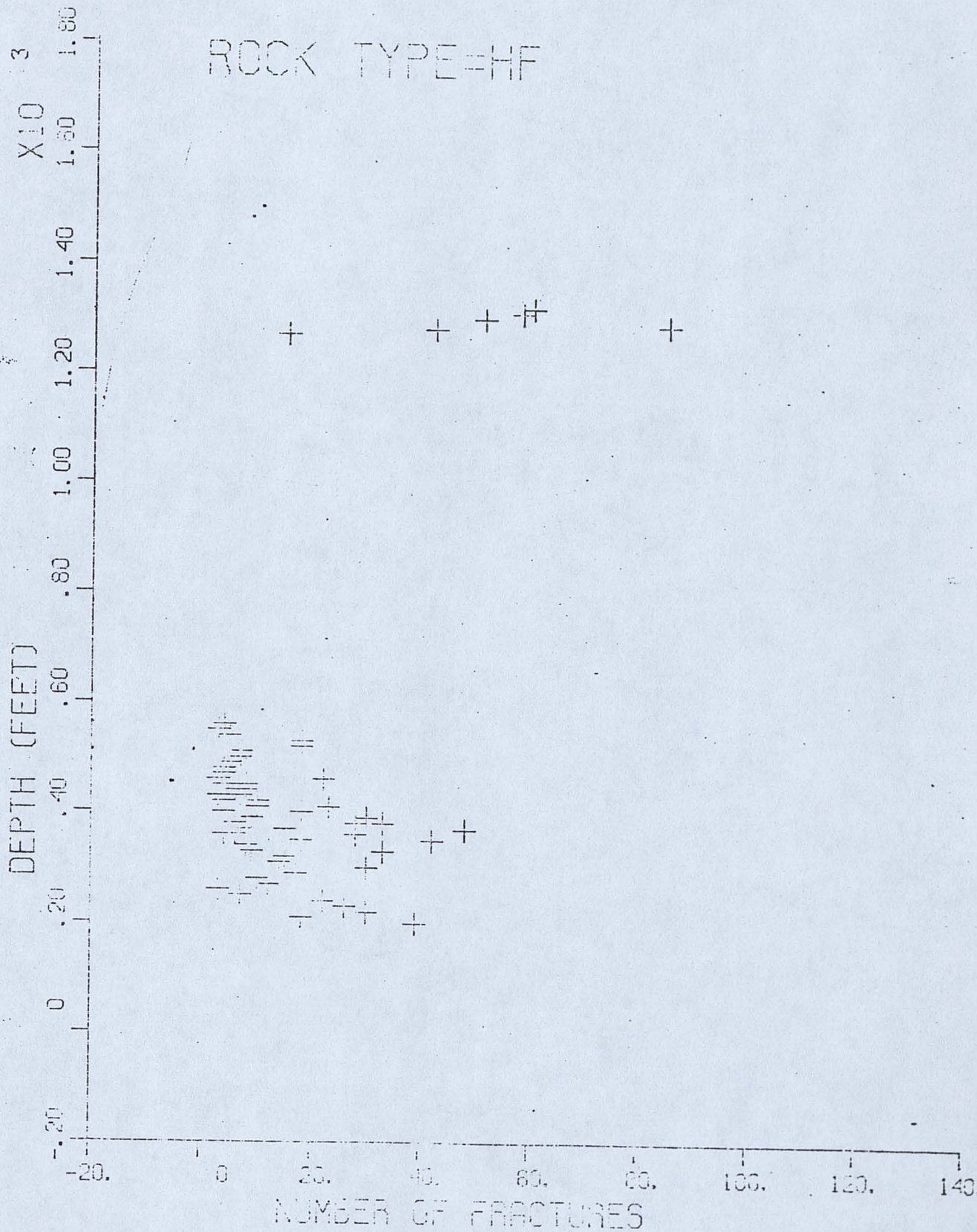


Figure 17. Plot of fracture density of hornfels versus depth.

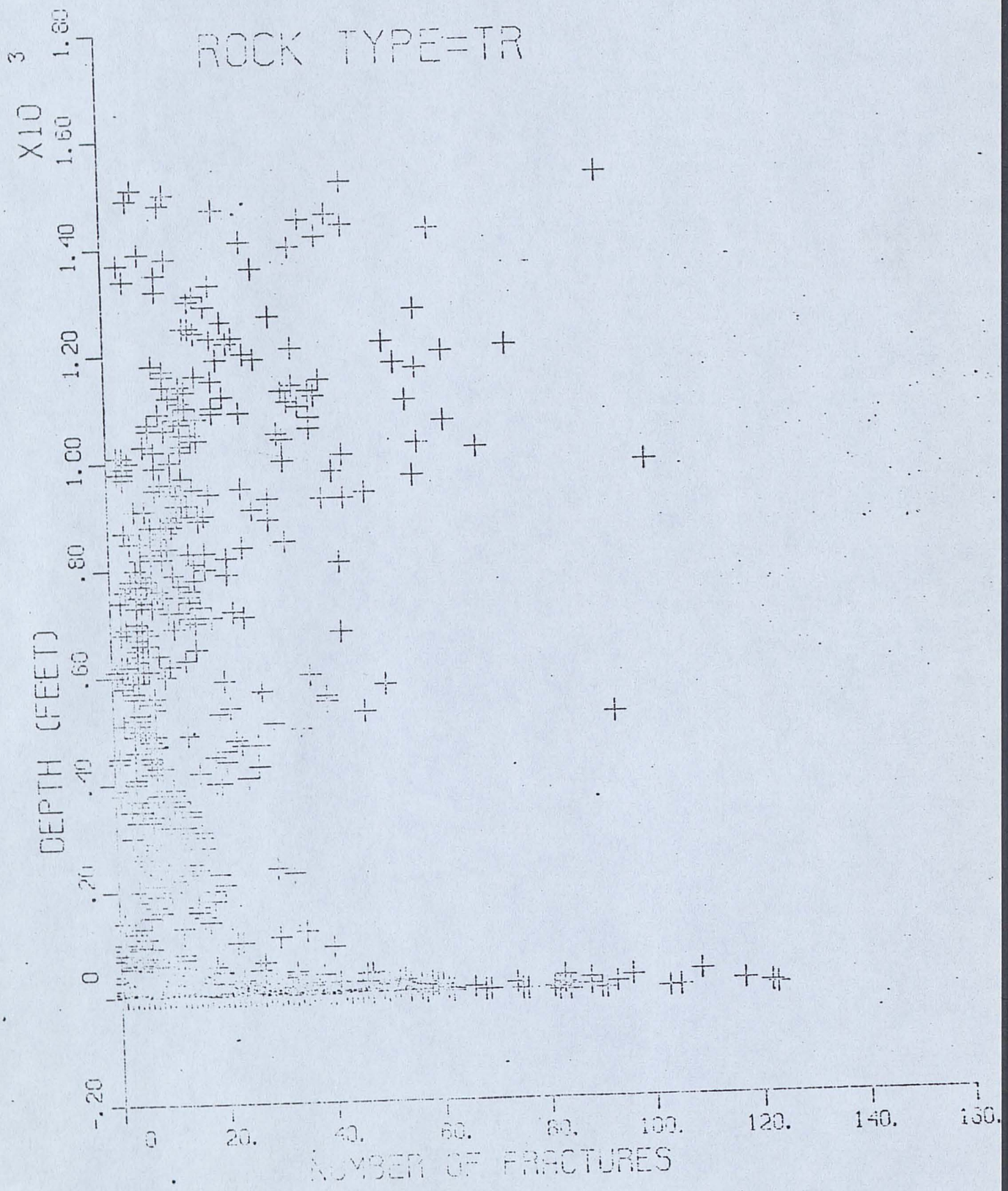


Figure 18. Plot of fracture density of tectolitic rocks versus depth.

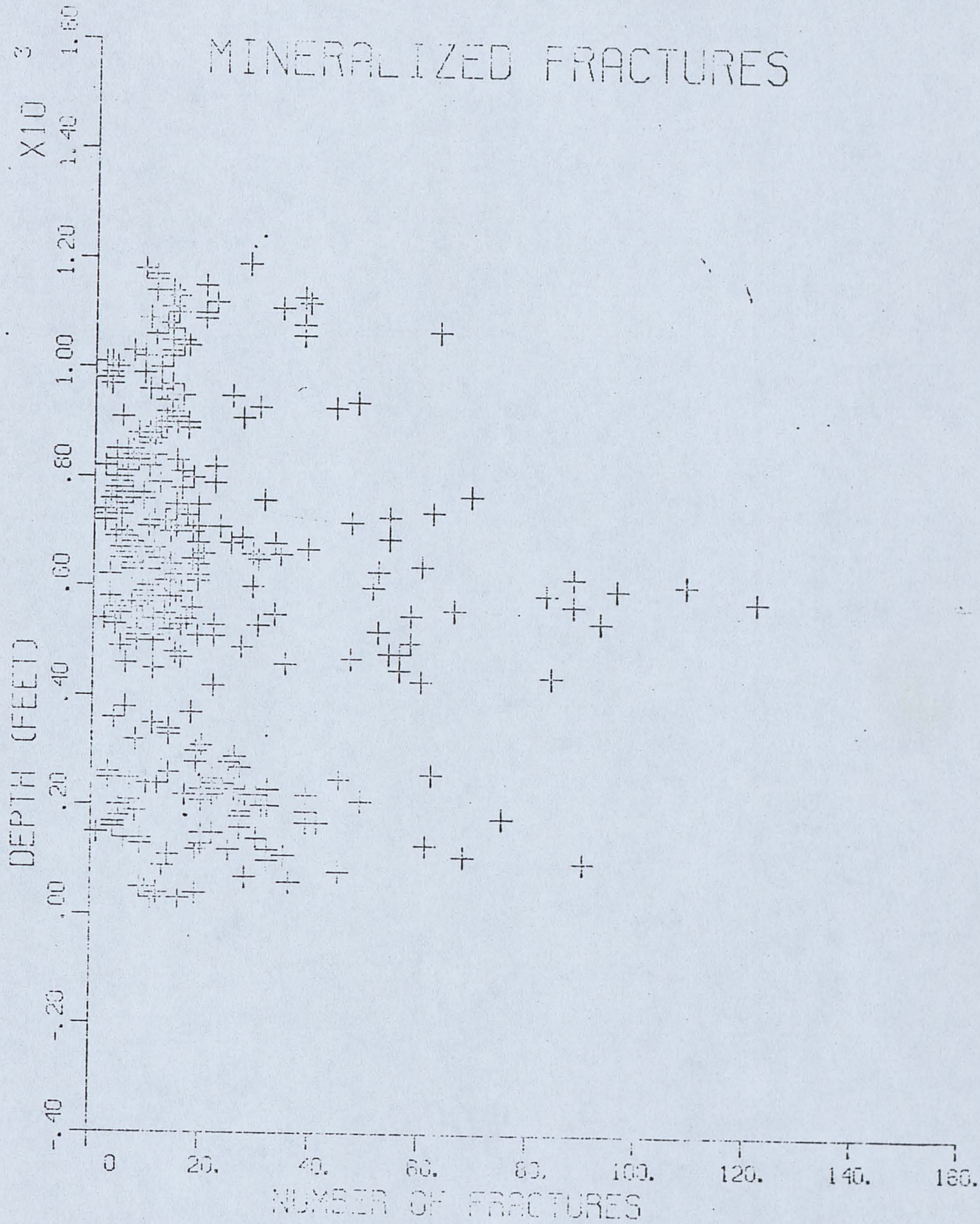


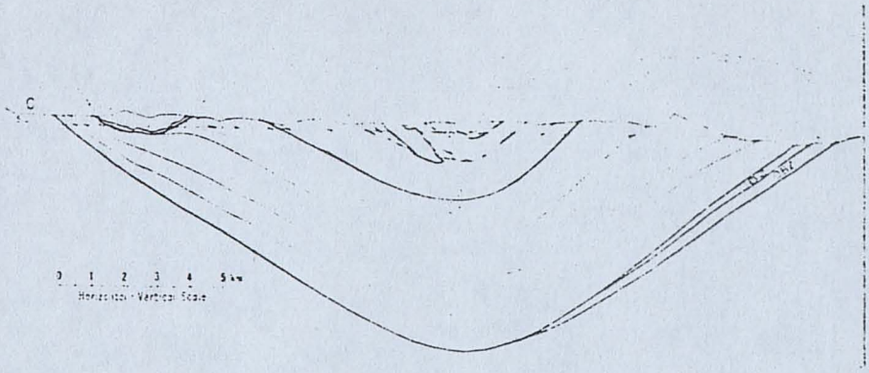
Figure 19. Plot of fracture density of rocks with visible sulfide mineralization versus depth.

Figure 20. Schematic cross sections of layered intrusions.

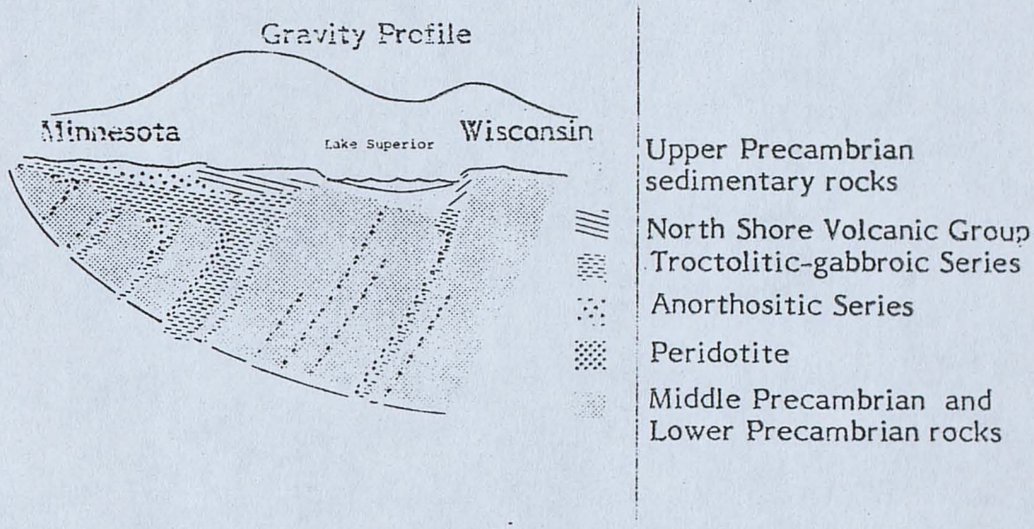
A. Schematic cross section characteristic of many layered intrusions (Wager and Brown, 1967). This general funnel shape is defined by the layering of successively differentiated gabbroic rocks. The gravity anomaly profile for such an intrusion would be symetrical.

B. Schematic cross section of the Duluth Complex and associated Keweenawan rocks. Foundering of crustal blocks as postulated by Weiblen and Morey (Appendix I, p. 20-23) could produce the asymetric magma chambers which are suggested by the geology in the Hoyt Lakes--Kawishiwi area. The model also provides a mechanism for a complex distribution of pre-Keweenawan crustal rocks within the Keweenawan rift in the Lake Superior region that would be consistent with the observed gravity anomaly profile.

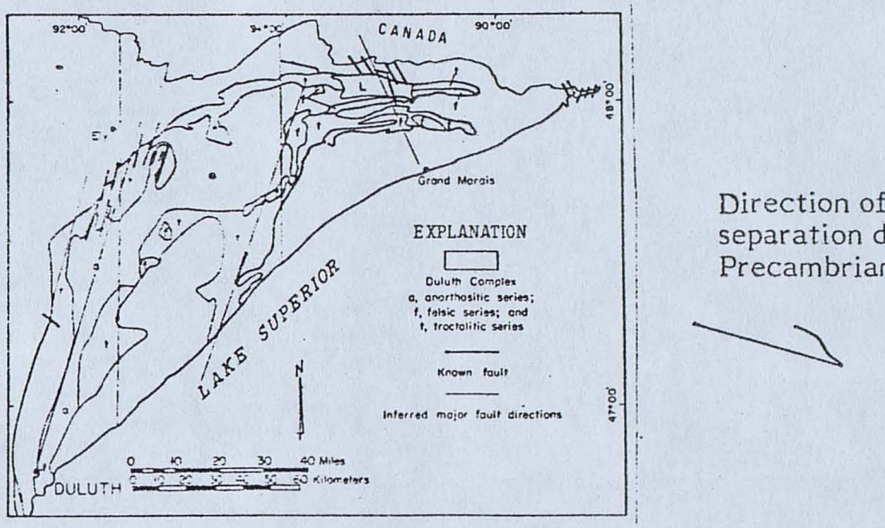
C. Generalized structural map of the Duluth Complex (from Weiblen and Morey, 1975, Appendix I, p. 18). This map illustrates the coincidence of the northeast trending faults in the Hoyt Lakes--Kawishiwi area and the basal contact of the Duluth Complex between Duluth and Hoyt Lakes. Subsidence and/or lateral separation of the bedded and jointed Middle Precambrian Animikie Group rocks along the northeast trending faults could have produced the void space for the Duluth Complex. This would have resulted in a northeast trend to asymetric magma chambers as shown in Figure 21. In light of this model, any variations in characteristics of layered rocks should be viewed in cross sections normal to the northeasterly trend of the faults rather than normal to the more easterly trend of the contact in the Hoyt Lakes--Kawishiwi area.



A. Cross section of the Kiglipait intrusion (After Wager and Brown, 1967, p. 547).



B. Schematic northwest - southeast cross section of the Duluth Complex and associated Keweenawan rocks.



C. Generalized structural map of the Duluth Complex (from Weiblen and Morey, 1975, Appendix 1, p. 18).

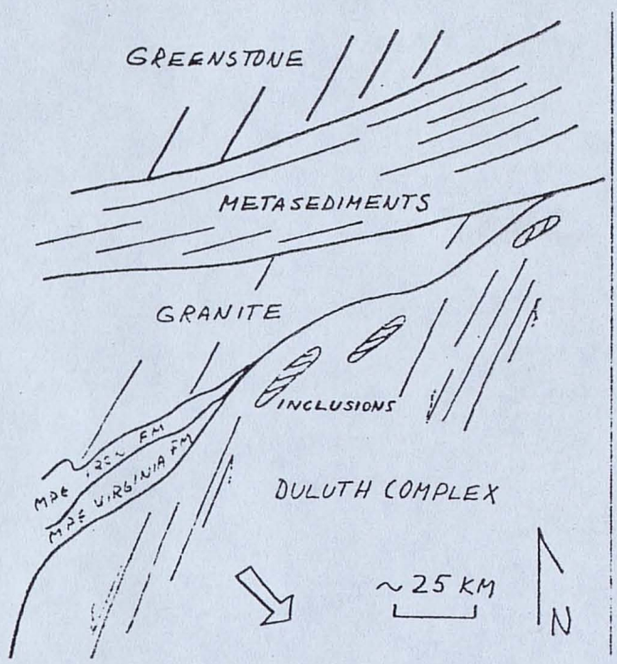


Figure 21. Schematic map of the contact zone of the Duluth Complex in the Hoyt Lake--Kawishiwi area. This map illustrates the left lateral offsets in the contact of the Duluth Complex which are developed where the base of the Complex intersects the Middle Precambrian--Lower Precambrian boundary. Perhaps the northern terminus of the Midcontinent Rift was determined by this boundary.

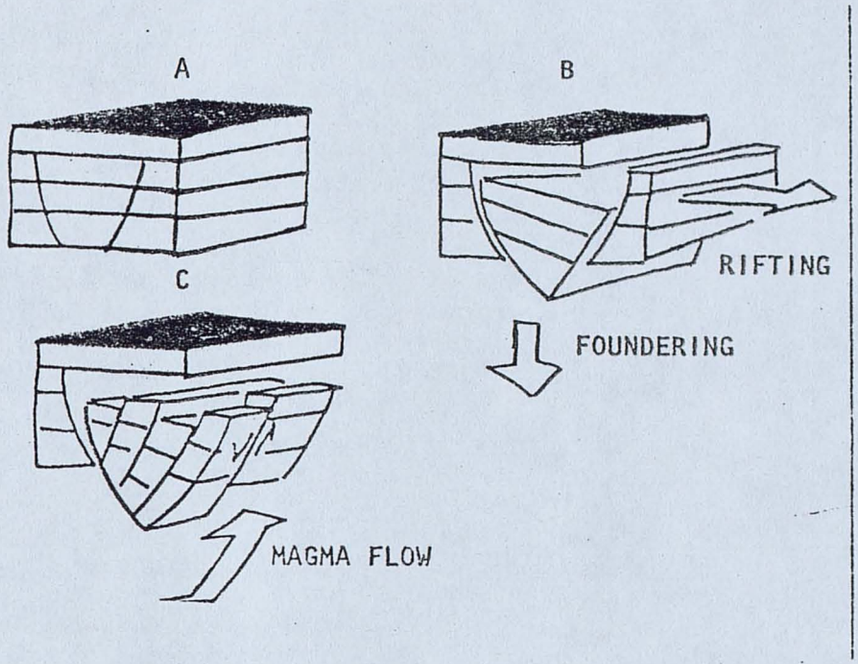


Figure 22. Schematic block diagram of the contact zone of the Duluth Complex in the Hoyt Lakes—Kawishiwi area. Sketches A, B, and C show the progressive foundering and separation that rifting could have produced in a sequence of bedded Middle Precambrian rocks in the Hoyt Lakes—Kawishiwi area. Regional rifting dynamics could have introduced major fractures as indicated in A, but local planes of weakness produced by bedding and jointing in the rocks could have resulted in magma chambers with an irregular floor and interrupted continuity along strike (B and C).

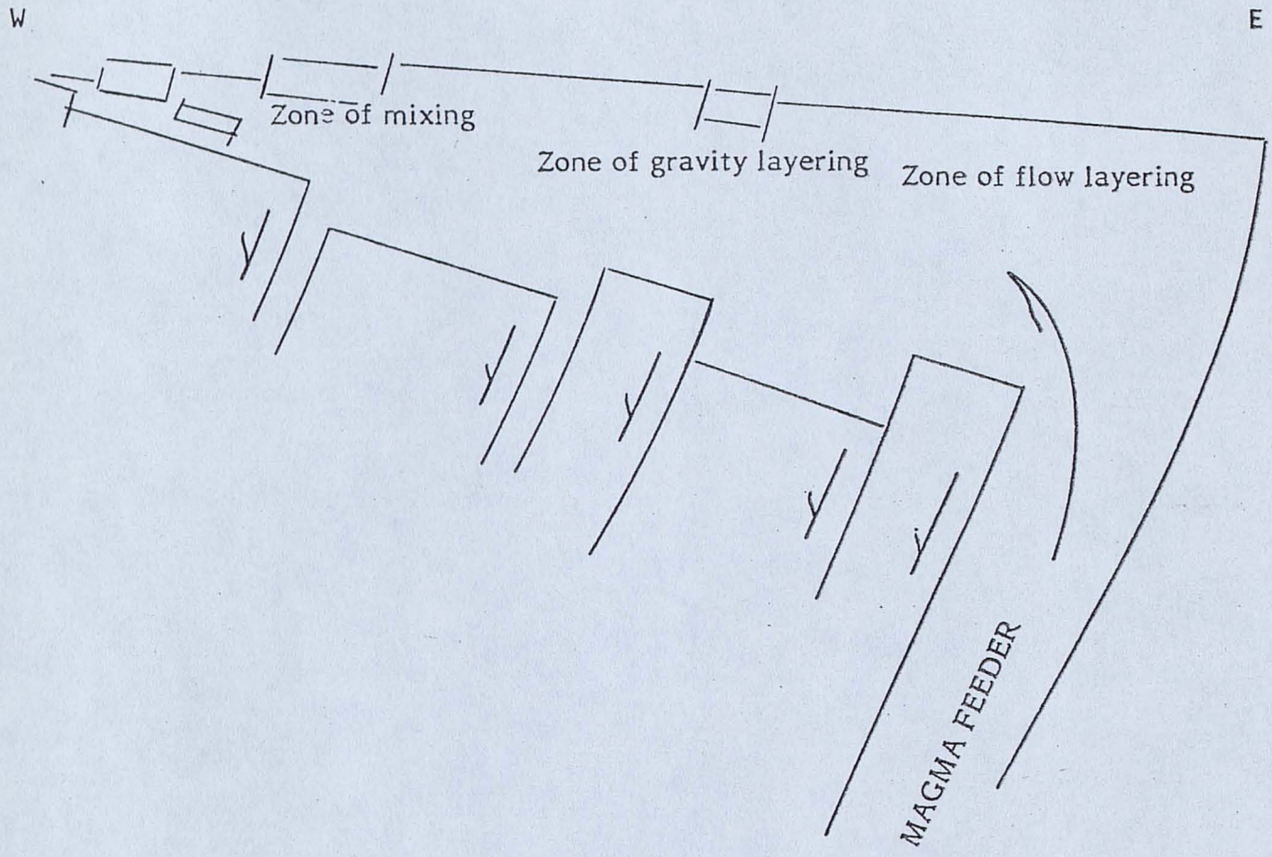


Figure 23. Schematic E-W cross section of the Duluth Complex in the Hoyt Lakes-Kawishiwi area. The model of emplacement of the troctolitic gabbroic rocks suggested by Weiblen and Morey, 1975 (Appendix I, p. 21-23) carries the implication that there would be a gradation between flow layered, gravity layered and non-layered rocks as indicated in the figure. It will be possible to construct cross sections to check this using the petrologic data to be obtained in the Hoyt Lakes traverse samples, drill core data and data on the map of the bedrock geology.

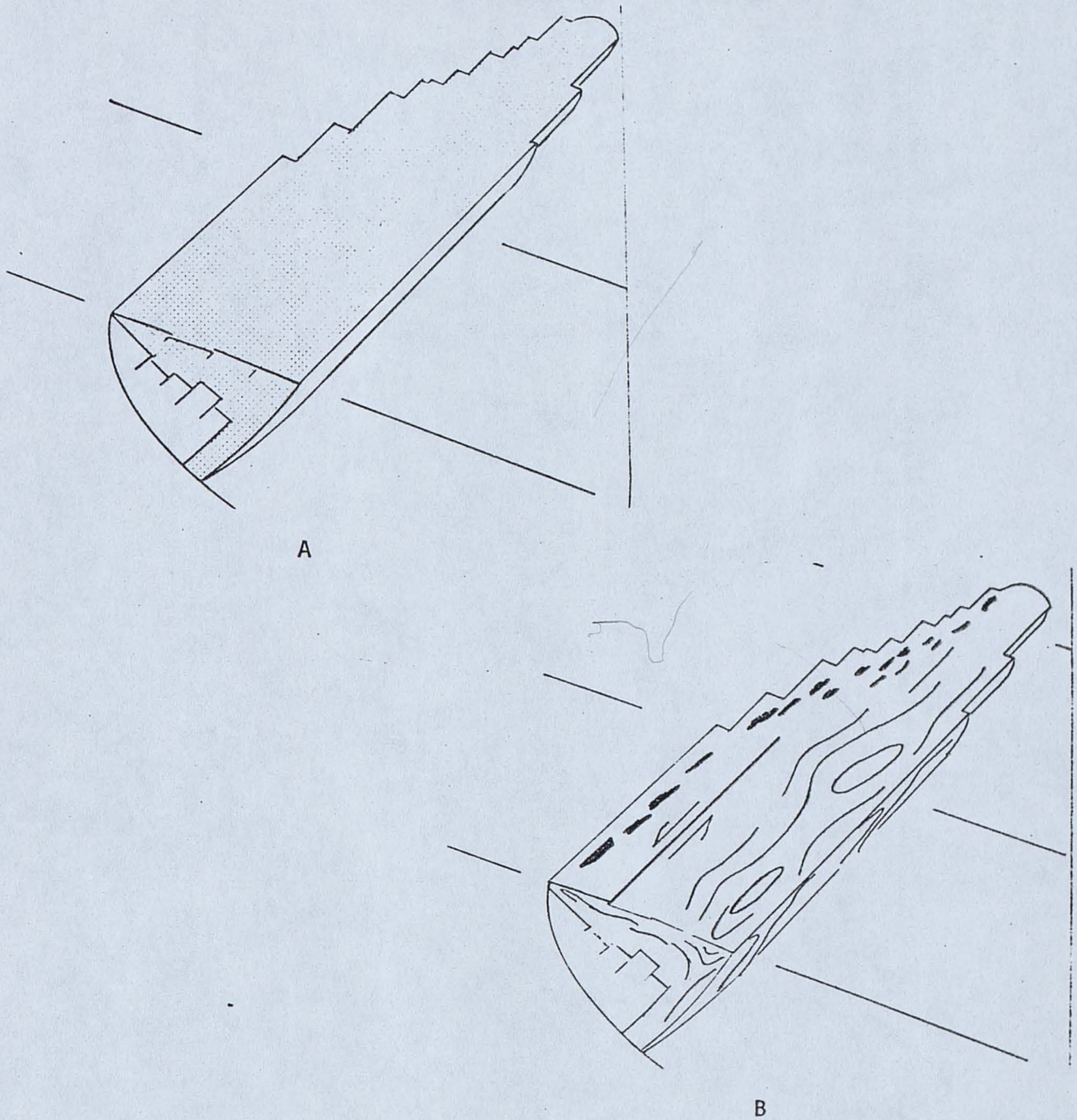


Figure 24. Hypothetical three dimensional view of a magma chamber for the troctolitic- gabbroic rocks which is consistent with the geologic relationships in the Kawishiwi area and a rifting model for their origin (Appendix I, p. 20-23).

A. View of a hypothetical magma chamber from the vicinity of Sec. 17, T.60N., R.10W. northeastward toward the INCO minesite in Sec. 25, T.62N., R.11W.

B. Hypothetical magma chamber shown in A with distribution of inclusions (black), left lateral northeast trending fault, and postulated flow pattern of magma which could have developed this chamber to produce the distribution of textures found in the troctolitic-gabbroic rocks in the Kawishiwi area.

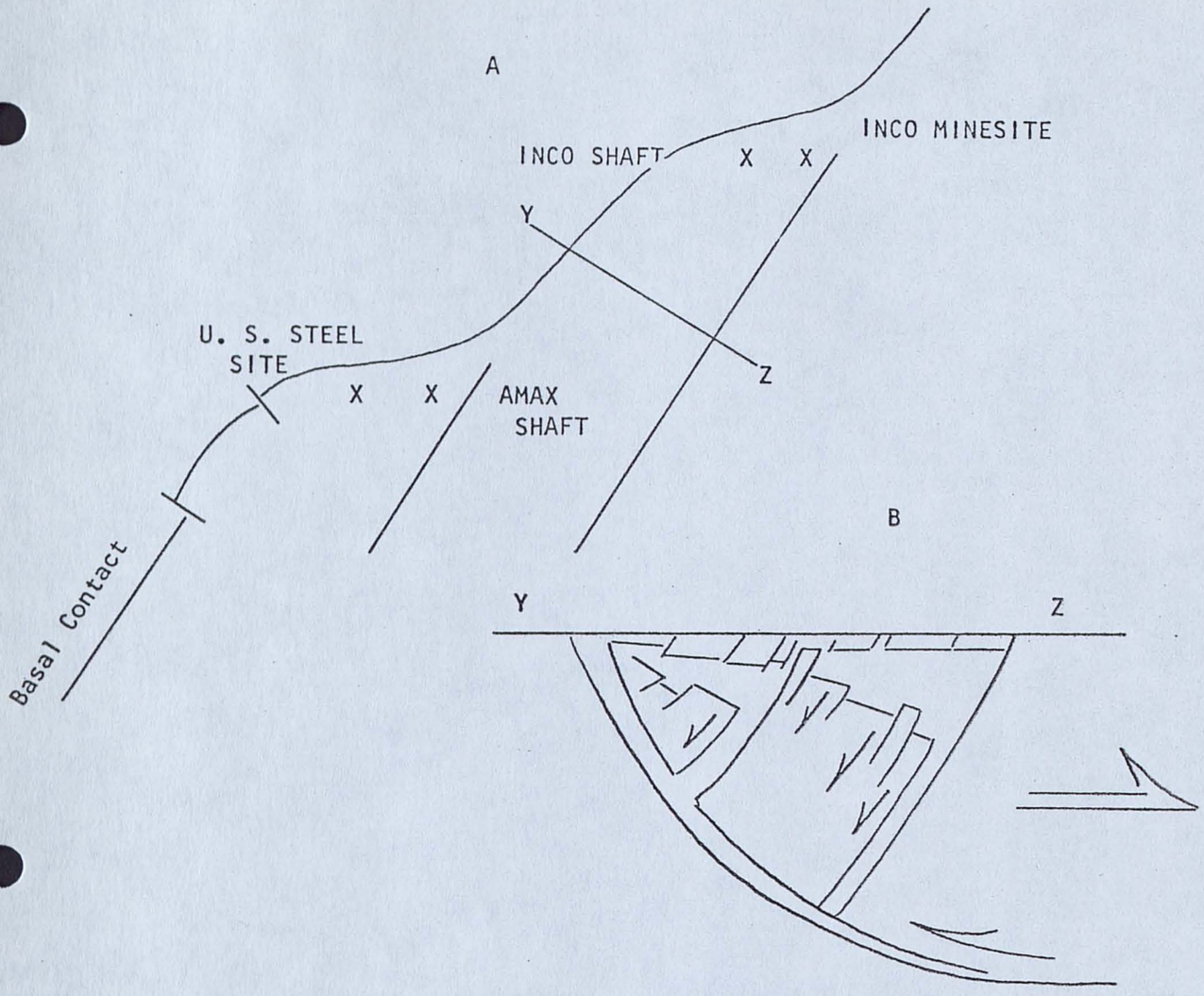


Figure 25. Schematic illustration of the relationship between mineralized sites of current economic interest and configuration of the basal contact of the Duluth Complex in the Hoyt Lakes—Kawishiwi area.

A. Schematic map of the configuration of mineralized sites and the basal contact.

B. Cross section of mineralized zones.

If one assumes that the location of the AMAX shaft and INCO Spruce Road minesite were chosen because they represent the highest sulfide concentrations of significant size in the contact zone, it is interesting to note that they are located in the vicinity of left lateral offsets in the basal contact (A). Conceivably these are also the down-faulted sides of the floor of the Complex as shown in B. This environment would provide maximum fracturing and mixing of country rock with magma to promote reactions (table 2) associated with mineralization.

TABLES

Table 1. General characteristics of some major hornfels inclusions in the Hoyt Lakes-Kawishiwi ar (after Tyson, 1975)

	Erie	Dunka Railroad	Reserve	Colvin Creek
Mineralogy	plag + aug + ilm ±olv ± amph ± bio	plag + aug + ilm ±olv	plag + aug + olv	plag + aug + mgt
	Plag An_{45}-An_{54}	Plag An_{68}-An_{75}	Plag An_{67}-An_{68}	Plag An_{52}-An_{69}
	Aug (Mg/Mg+Fe) .49-.75	Aug (Mg/Mg+Fe).66-.77	Aug (Mg/Mg+Fe).74-.77	Aug (Mg/Mg+Fe).64-.78
Amygdules	common-borders sharp	present-borders not sharp	few-borders poorly defined	present-borders not sharp
Phenocrysts	common-partly recrystallized	less common-recrystallized	not present	less common-partly recrystallized
Texture	granoblastic, commonly foliated	granoblastic, sometimes foliated	granoblastic, rare weak foliation	granoblastic, sometimes foliated
Flows	easily distinguished	hard to dis-distinguish	not present	not seen
Miscellaneous	metamorphosed basalt dike, rare granitic dikes	common dikes of peridotite, granite and olivine gabbro	common dikes of granite and troctolite	few dikes of plag
Location	Exposed in Sec. 18 T.59N., R.13W. for 215m along R.R. cut (Fig.15,p.29) also one isolated O.C. N.50m, SE of tracks (J.Dunlavey)	Exposed in Sec.33 T.60N., R.12W. known outcrop: 670m along RR rockcut also several isolated exposures ∿50-100m. SE of RR tracks (Fig. 24, p. 41)	Exposed in Sec. 32, T.60N., R.12W. Known outcrop: 150-200m along RR cut (Fig. 10, p. 23)	Exposed in Secs. 27,33,34 T.58N., R.13W., Secs. 4,9, T.59N., R.13W.
Size	inferred size .2-.3 km x 1.5-2 km (fig. 3, p. 4)			total inferred size of body: 1-2 km x 6-8 km crescent shaped Fig. 4, p. 15

Table 2. Hypothetical, diffusion controlled reactions which may have occurred in the contact zone of the Duluth Complex in the Hoyt Lakes--Kawishiwi area.

$Mg^{++} + Fe^{++} + Ca^{++} + Na^{+} + Ti^{+4} + AlSi_3O_8^{-} + SiO_4$
$Cu^{++} + Ni^{++}$

NORMAL MAGMA

+

$S + K^{+} + H_2O$

ADDITION BY DIFFUSION FROM COUNTRY ROCKS

$(MgFe)_2SiO_4 + (Ca,Na)_{1-2}Si_{2-3}Al_{1-2}O_8 + Ca(Fe,Mg)Si_2O_6 + FeTiO_3$

Olivine Plagioclase Clinopyroxene Ilmenite

TROCTOLITIC-GABBROIC ROCKS BEYOND THE CONTACT ZONE

$K(Mg,Fe)_3Si_3AlO_{10}(OH)_2 + Fe_3O_4 + (MgFe)_2Si_2O_6 + (Fe, Cu, Ni)_xS_y$

Biotite Magnetite Orthopyroxene Sulfide Solution

$(Mg,Fe)_6Si_4O_{10}(OH)_8 + Ca_2(Fe,Mg)_5Si_8O_{22}(OH)_2$

Serpentine Amphibole

ADDITIONAL MINERALS FOUND IN TROCTOLITIC-GABBROIC ROCKS IN THE CONTACT ZONE

The schematic reations above illustrate the change in the crystallization products of a basaltic magma by the addition of components indicated. Evidence for diffusion of these components into the basal contact zone of the Duluth Complex in the Kawishiwi area are given in Appendix II, Part 3, table 2 and figs. 6-12.

APPENDIX 1

The Duluth Complex--a petrologic and tectonic summary by P.W. Weiblen and G.B. Morey, Minnesota Geological Survey Reprint Series 28, 1975.

APPENDIX II

Textures, Plagioclase grainsize, Mineral proportions, and mineral compositions of Duluth Complex rocks in the Hoyt Lakes--Kawishiwi area.

Part 1--Photographs of rock textures from outcrops.

Part 2--Photomicrographs of rock textures from thin sections.

Part 3--Table 1. Grain size measurements of plagioclase in troctolitic-gabbroic series rocks from the Kawishiwi area.

Table 2. Modal proportions of olivine, plagioclase, clinopyroxene, orthopyroxene, opaque minerals, biotite and symplectite in troctolitic-gabbroic series rocks from the Kawishiwi area.

Table 3. Electron microprobe analyses of olivine in troctolitic-gabbroic series rocks from the Kawishiwi area.

Table 4. Tabular data for Figures 4 - 12 and 15.

Figure 1. 62-10-30-97B: Detail of fine-grained hornfels with white plagioclase-rich segregations; scale in cm.

Figure 2. 62-10-30-84A: Detail of ago with 5-15 mm clusters of olivine and oxides; pyroxene evenly distributed; scale in cm., plagioclase is light-colored.

Figure 3. 62-10-30-74A: Detail of ago with 5-15 mm clusters of olivine, oxides and pyroxene; white to gray mineral is plagioclase; scale in cm.

Figure 4. 62-10-19-54A: Detail of agu; plagioclase (80%) is light-colored mineral; pyroxene (8-10%) and olivine (5-8%) make up majority of dark-colored minerals; scale in cm.

Figure 1

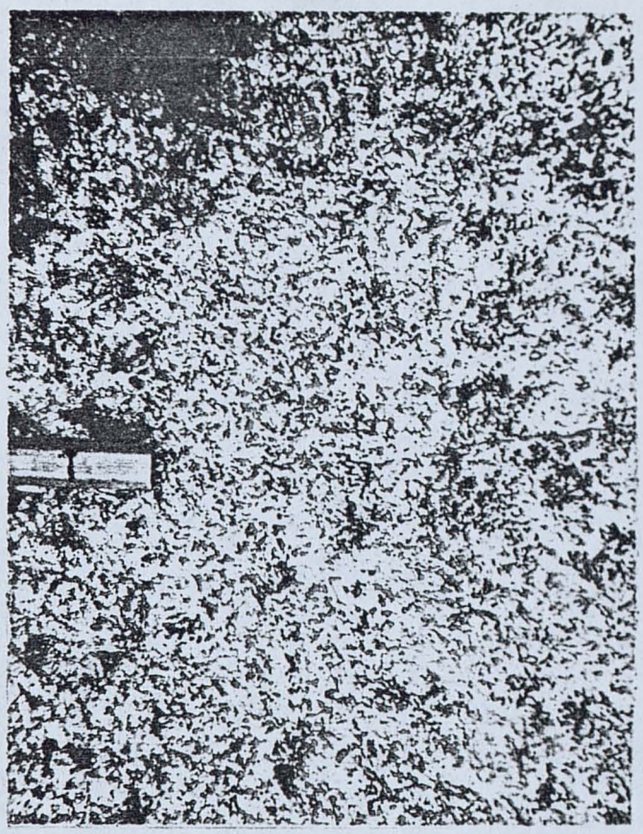


Figure 2

Figure 3

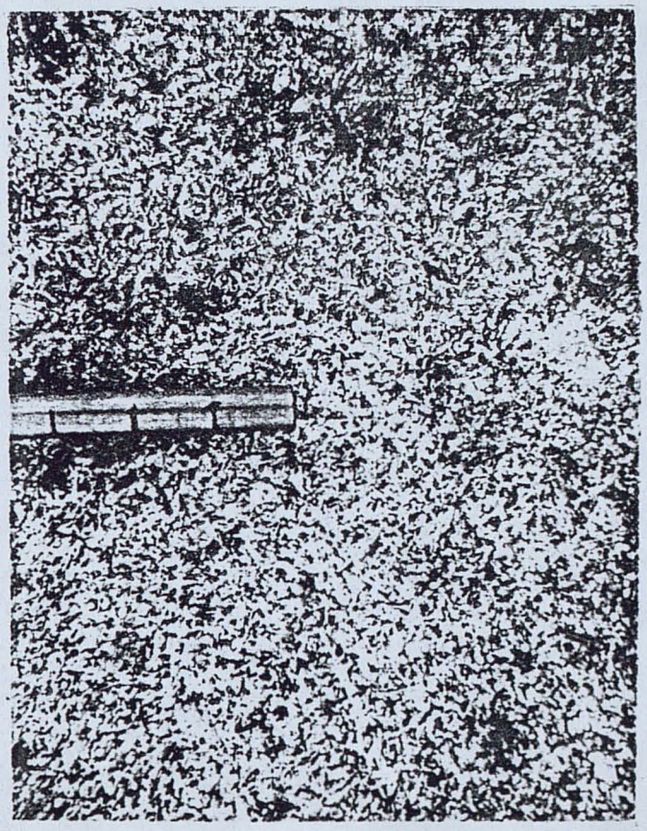


Figure 4

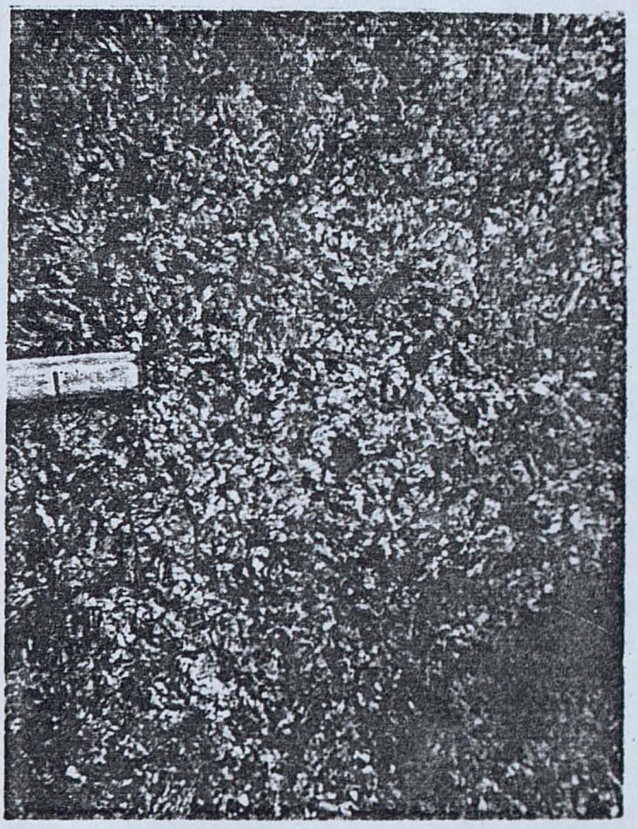


Figure 5. 62-20-19-64A: Detail of agu; fine- to medium-grained troctolitic anorthosite; plagioclase is white mineral.

Figure 6. 61-10-9-14A: Detail of anorthosite to troctolitic anorthosite with 2-3 cm clusters of olivine (not seen in photograph) and large (2 cm) crystals of plagioclase in fine-to medium-grained matrix of 85-90% plagioclase, 5-8% olivine, 3-4% pyroxene and 1-2% oxides.

Figure 7. 61-10-9-15B: Detail of agu with well-defined clusters (1-3 cm) of mafic minerals, scale in cm.

Figure 8. 61-10-9-11AB: Inclusion of ago-like rock in anorthositic gabbro to anorthositic troctolite, scale in cm.

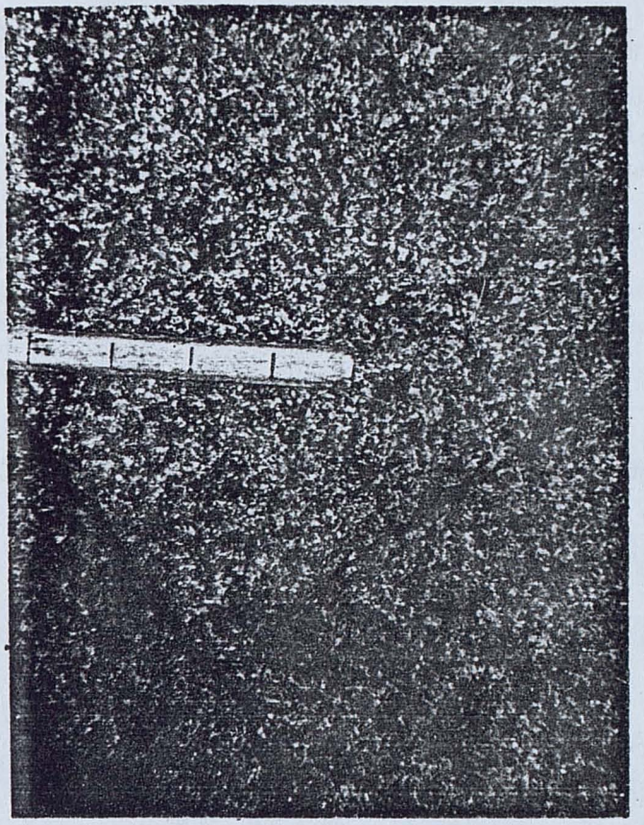


Figure 5

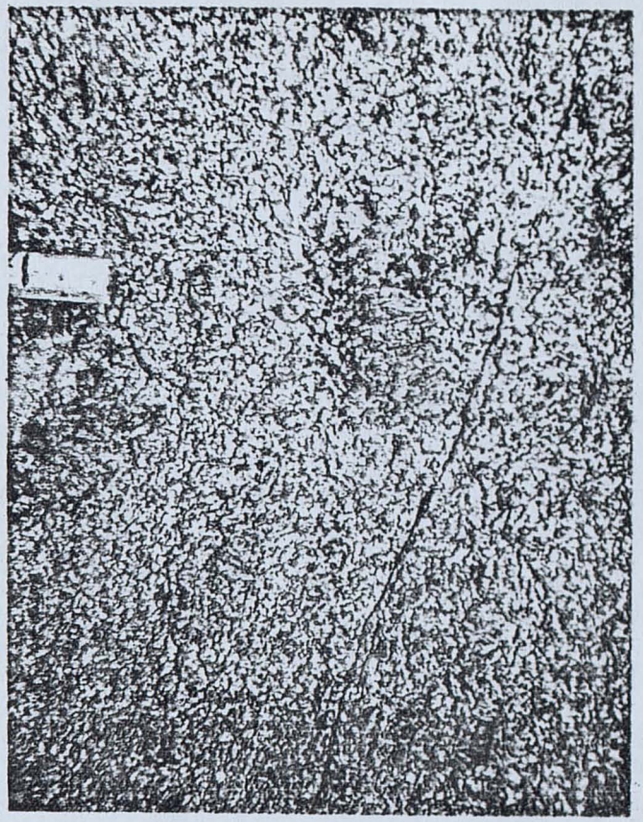


Figure 6

Figure 7

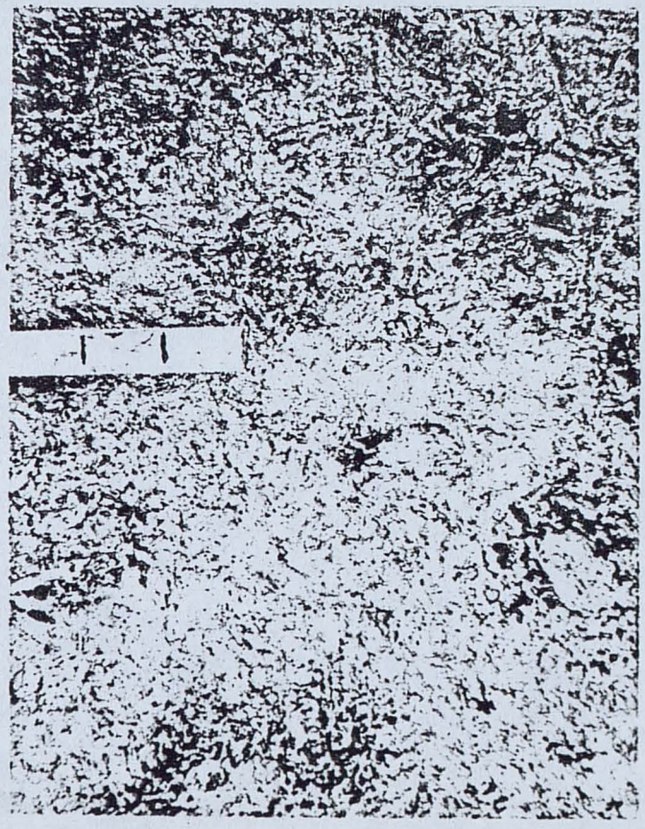


Figure 8

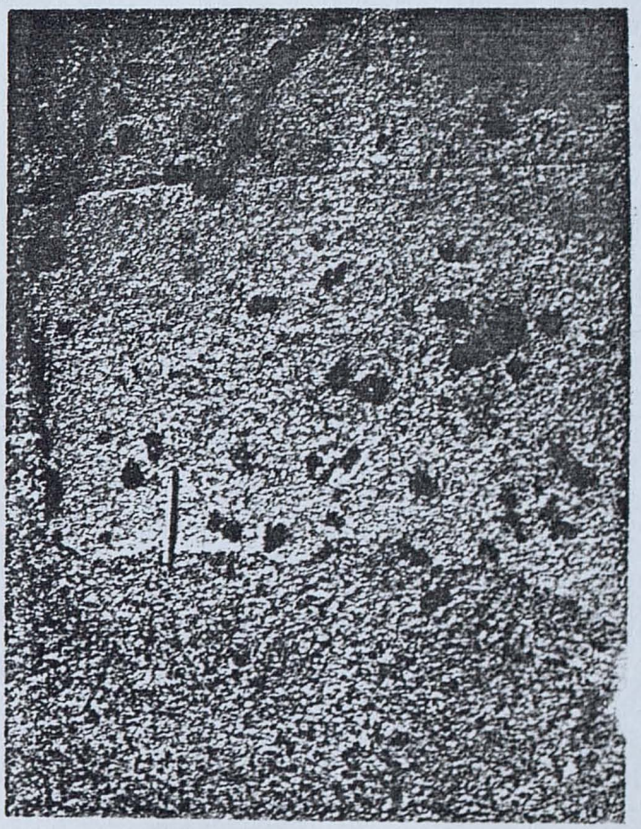


Figure 9. 61-10-9-11A: Detail of coarse-grained anorthositic troctolite host rock in Figure 8; gray mineral is plagioclase, scale in cm.

Figure 10. 61-10-9-19AC: Inclusion of coarse-grained rock similar to Figure 9 in medium-grained troctolitic anorthosite.

Figure 11. 61-10-9-12AB: Anorthosite "dikes" partially cored by olivine in medium- to coarse-grained troctolite to anorthositic troctolite.

Figure 12. 61-10-9-12A: Detail of troctolite to anorthositic troctolite in Figure 11; light-colored plagioclase (65-75%) and olivine (20-25%) are the major minerals.

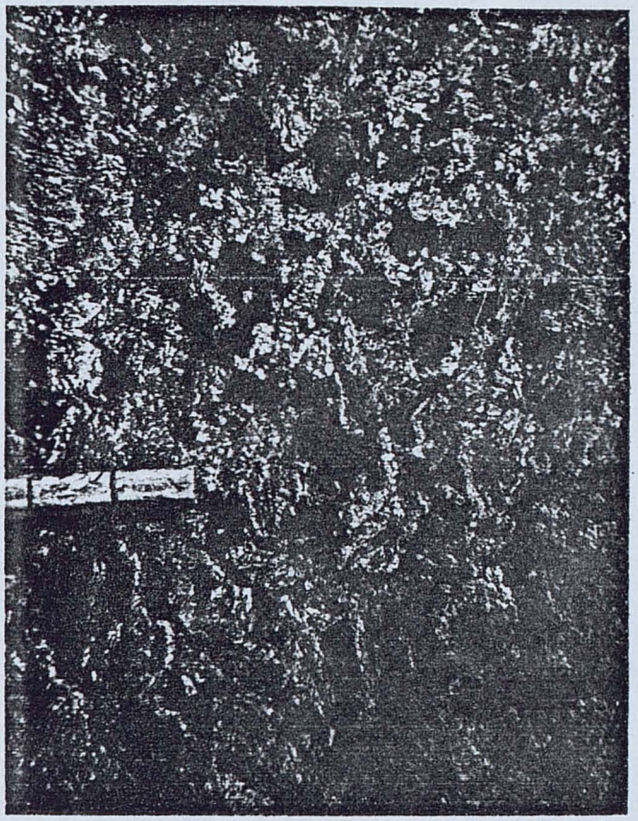


Figure 9

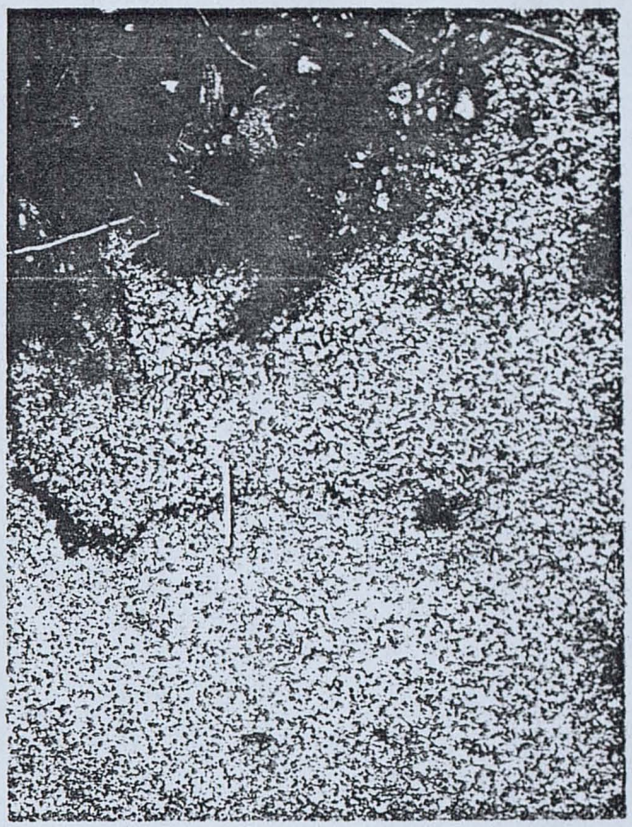


Figure 10

Figure 11

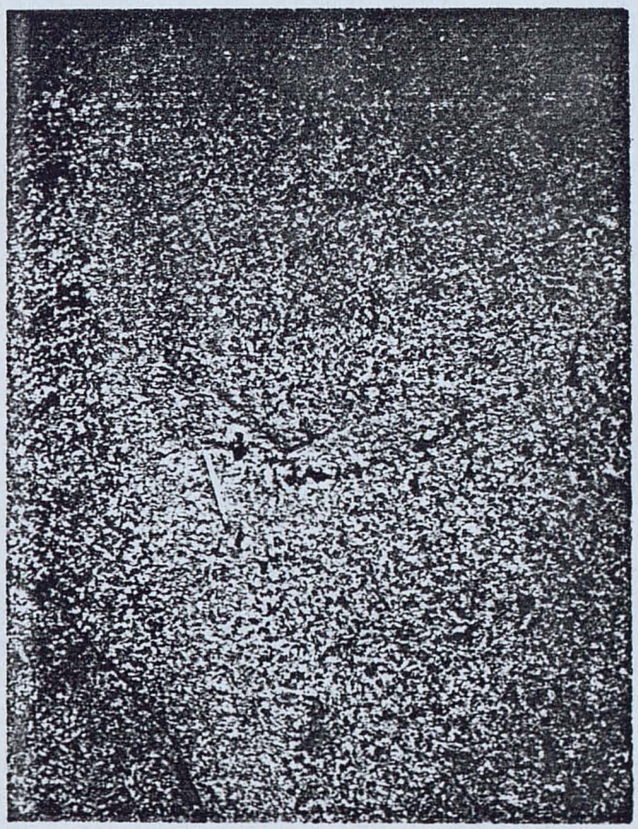


Figure 12

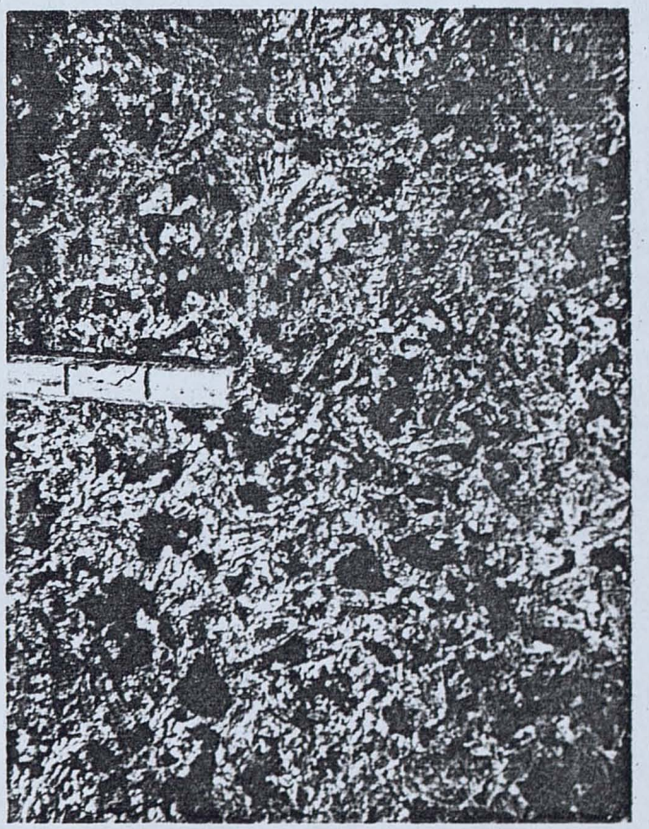


Figure 13. 61-10-9-18B: Synfomal structure trending N.60°E. defined by vague mineralogic layering and grain size variation.

Figure 14. 61-10-9-17A: Detail of medium-grained troctolitic anorthosite in right side of Figure 13; light-colored mineral is plagioclase.

Figure 15. 62-11-24-12A: Fine-grained hornfelsic appearing troctolite in tcz; scale in cm.

Figure 16. 62-11-26-62A: Medium- to coarse-grained troctolitic anorthosite in tcz; light colored plagioclase (80%) and olivine (15%) are major minerals present.

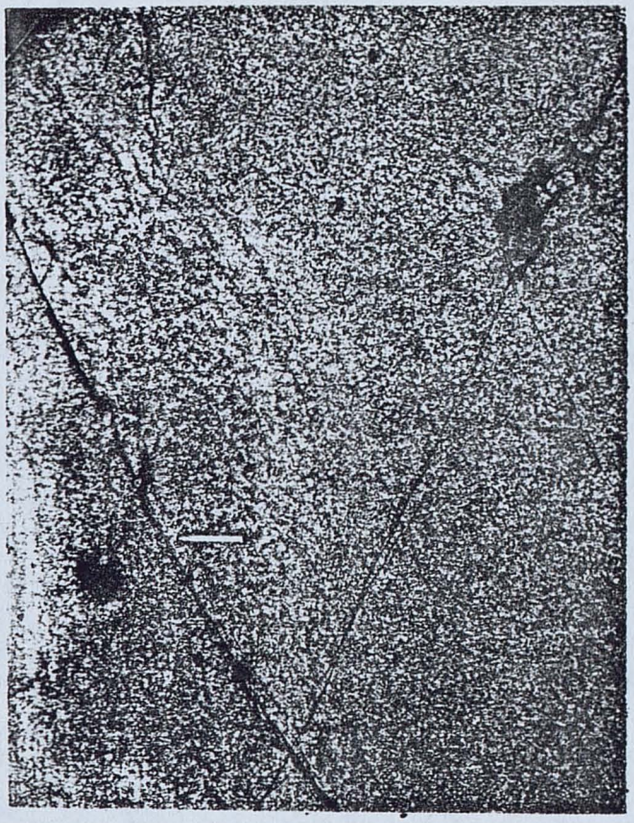


Figure 13

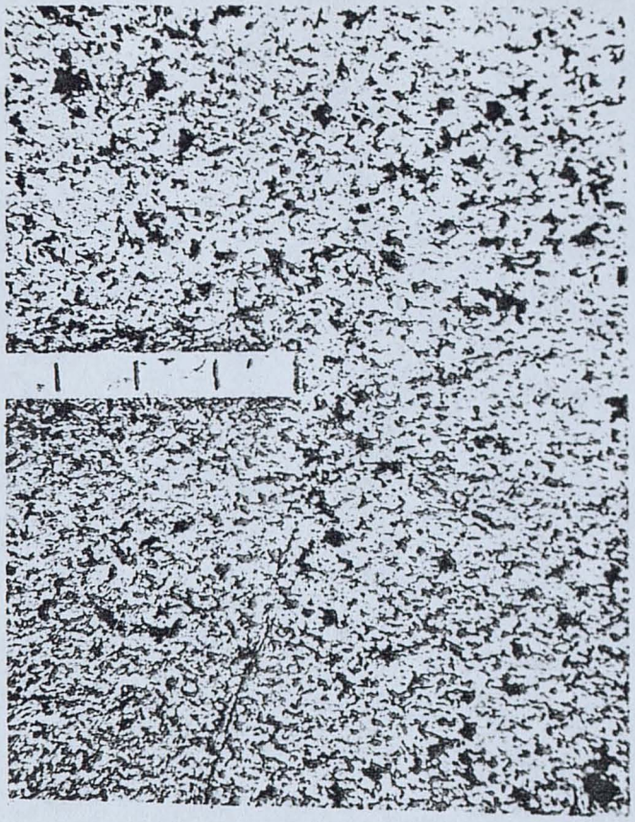


Figure 14

Figure 15

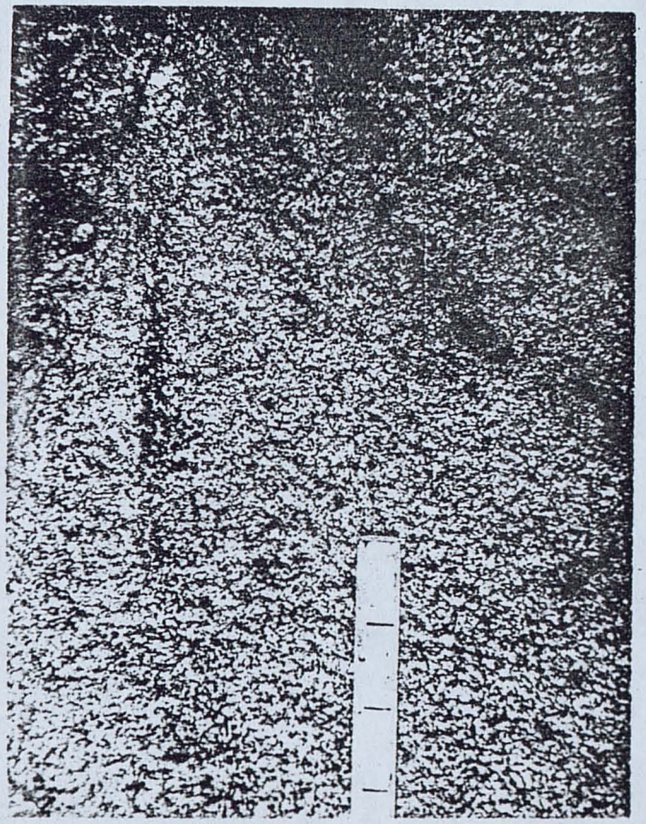


Figure 16

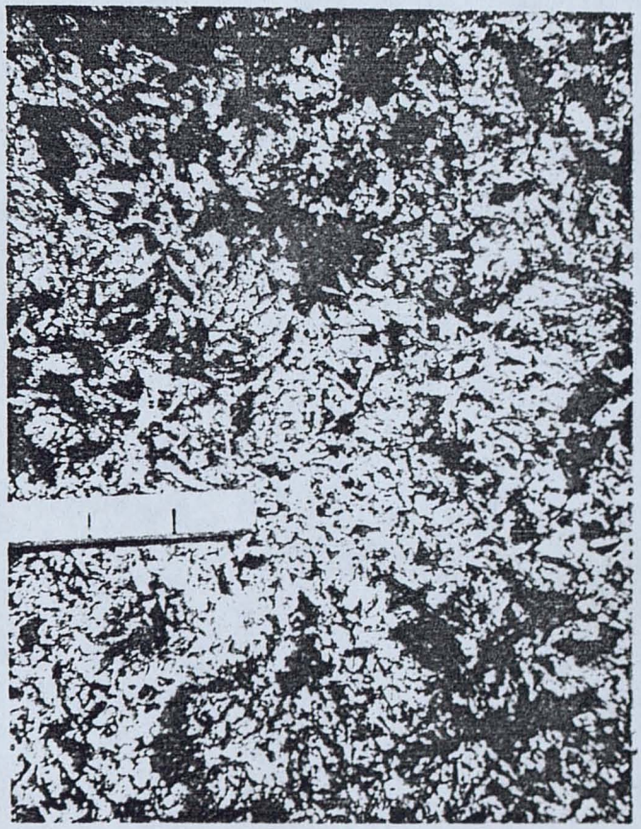


Figure 17. 62-10-19-75A: Medium-grained anorthositic gabbro to anorthositic troctolite of tt; plagioclase is light-colored; scale in cm.

Figure 18. 62-11-25-80B: Medium-grained troctolite of tt composed primarily of light-colored plagioclase (65-70%) and 20% olivine.

Figure 19. 62-11-25-84A: Medium- to coarse-grained augite troctolite of tt; white to gray plagioclase (75-80%), 10-15% olivine and 5-6% pyroxene.

Figure 20. 62-11-25-94B: Medium-grained troctolitic anorthosite with vague clusters of mafic minerals that may represent inclusion of ago in tt.

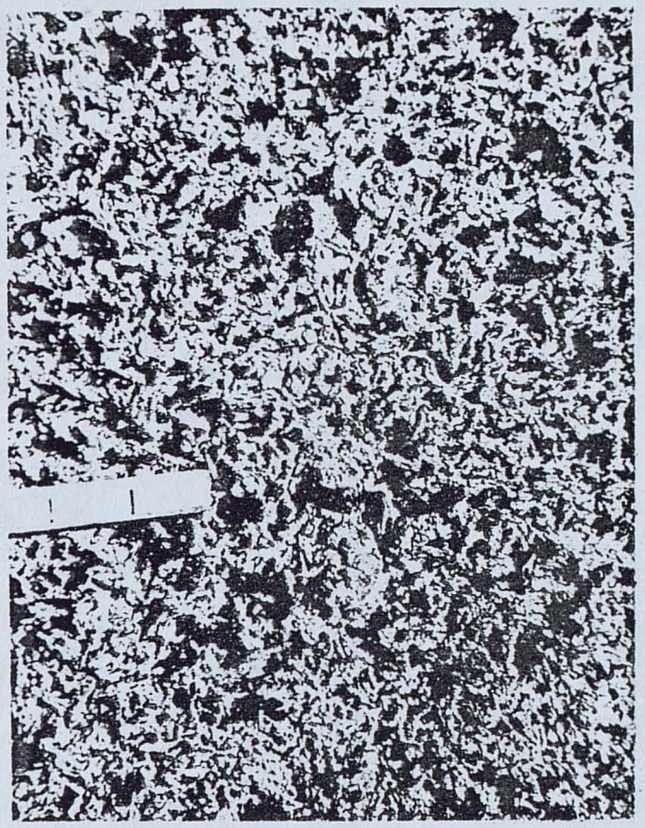


Figure 17

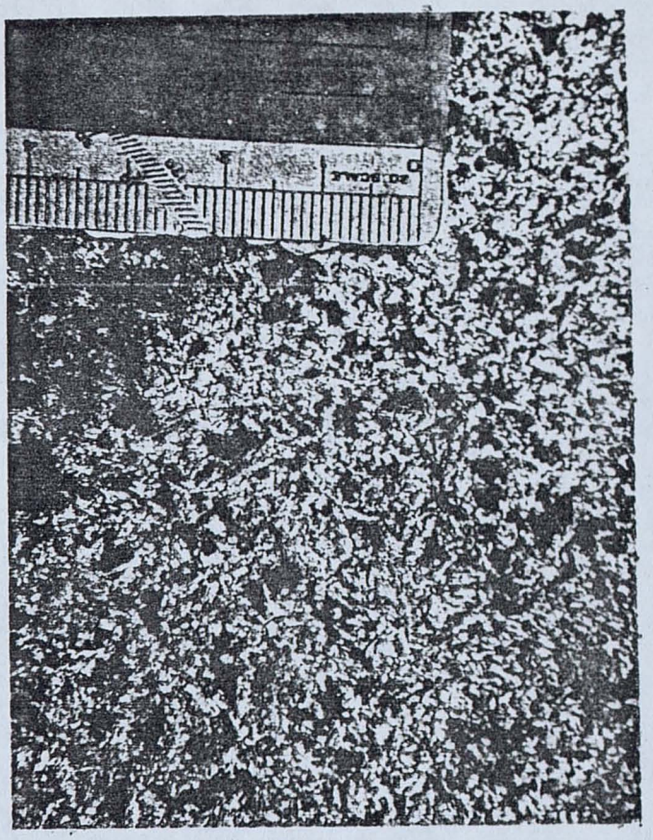


Figure 18

Figure 19

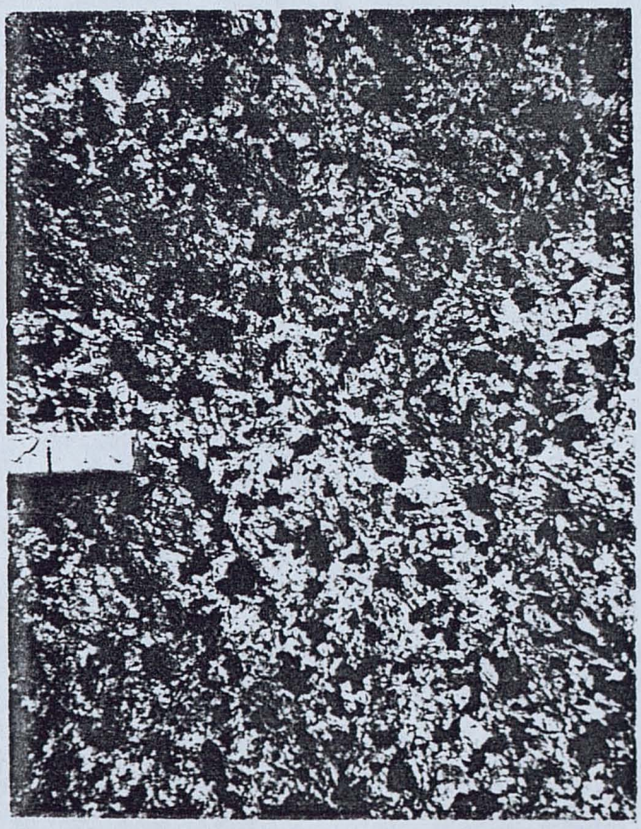


Figure 20

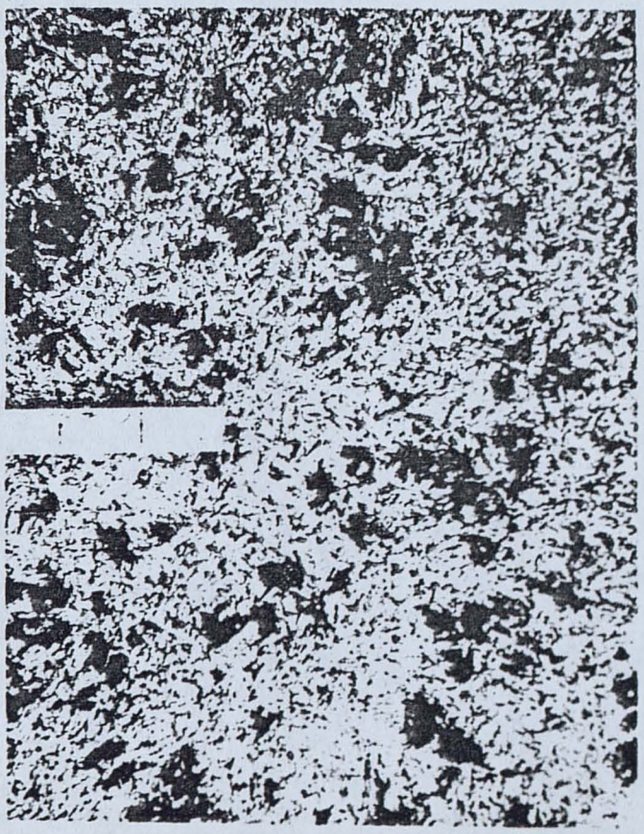


Figure 21. 62-11-25-91A: Medium- to coarse-grained anorthosite of ta; plagioclase is light mineral; traces of sulfide found in this outcrop; scale in cm.

Figure 22. 62-11-25-102A: Medium-grained troctolitic anorthosite of ta with hydrothermally altered mafic minerals; light-colored mineral is plagioclase.

Figure 23. 62-11-16-64A: Medium- to coarse-grained anorthosite of ta near Spruce Road; plagioclase is light-colored mineral.

Figure 24. 59-12-10-2A: Medium-grained anorthositic augite troctolite found in Railroad troctolite; plagioclase is light-colored mineral.

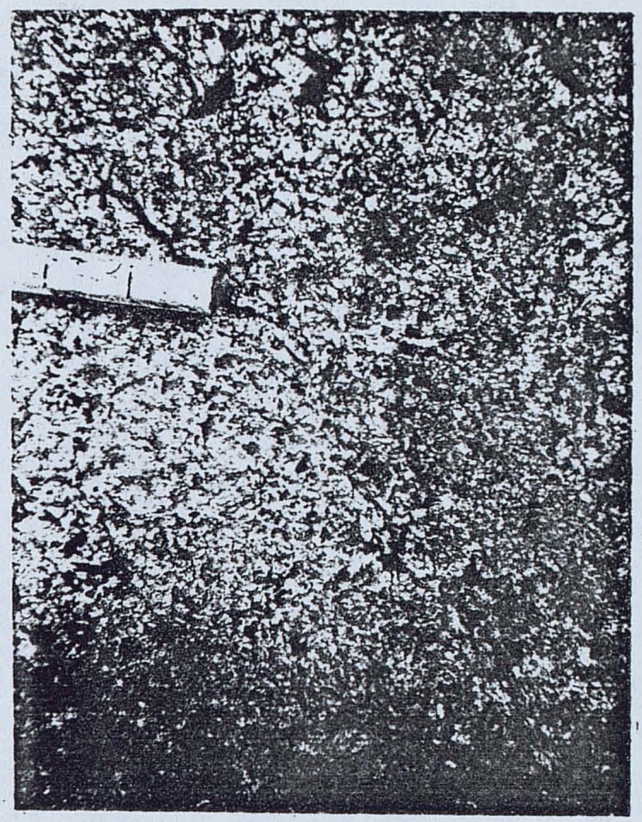


Figure 21

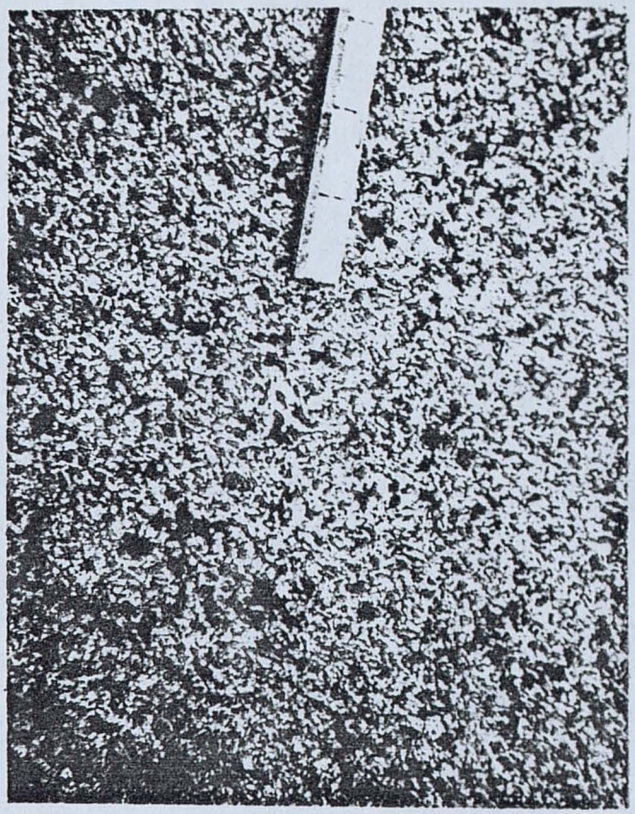


Figure 22

Figure 23

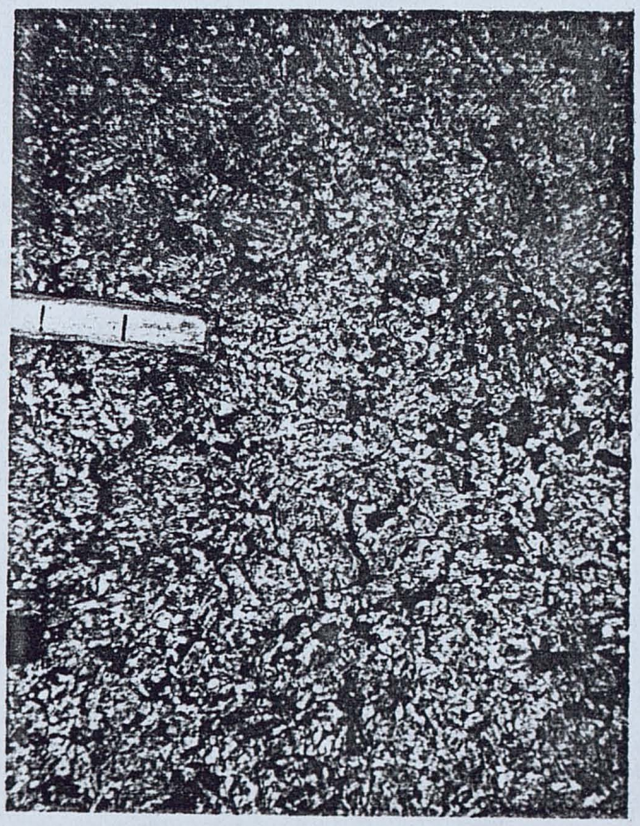


Figure 24

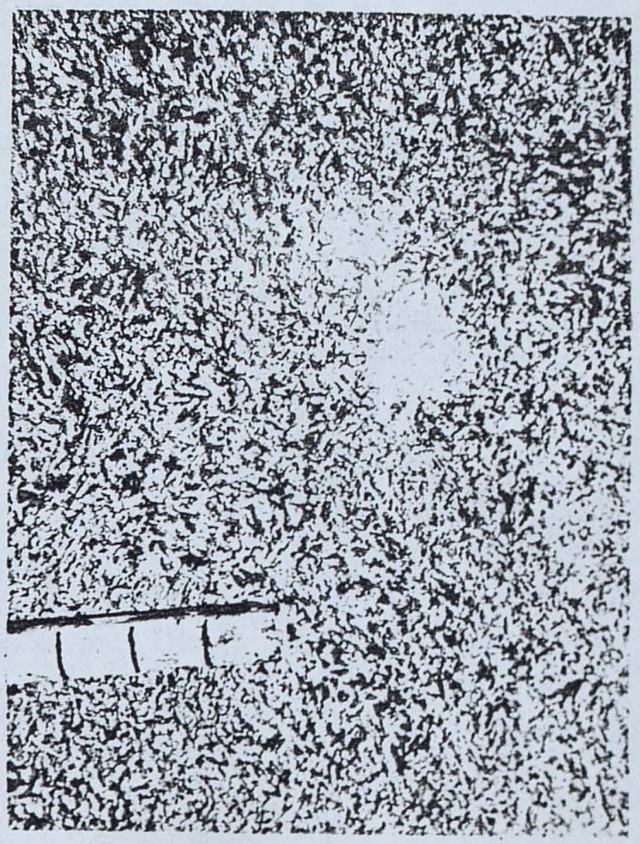


Figure 25. 59-13-22-1A: Medium-grained olivine-gabbro to troctolite of the Partridge River troctolite; white mineral is plagioclase; scale in cm.

FIgure 26. 59-13-22-3BC: Anorthositic inclusion (upper half of picture) in Partridge River troctolite.

Figure 27. 59-13-22-BB: Detail of troctolite in Figure 26; light-colored mineral is plagioclase.

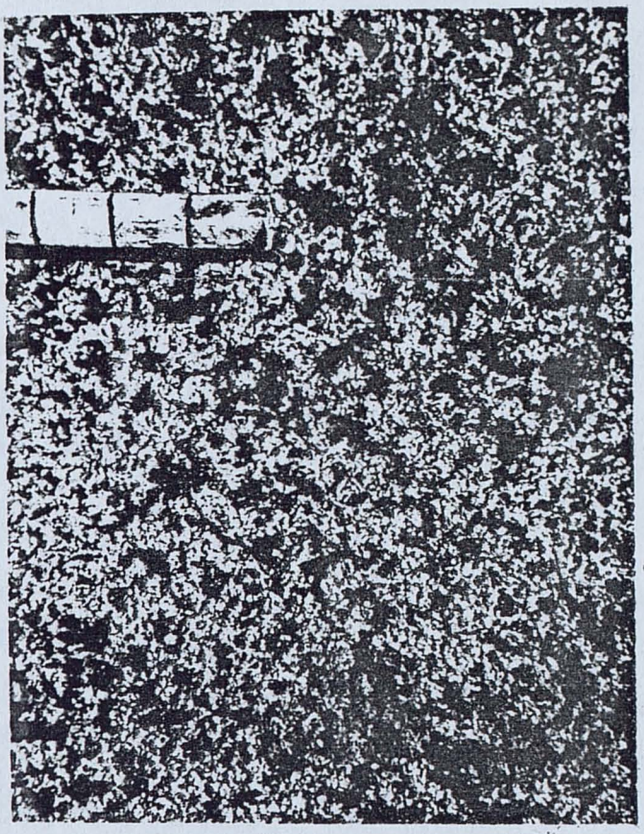


Figure 25

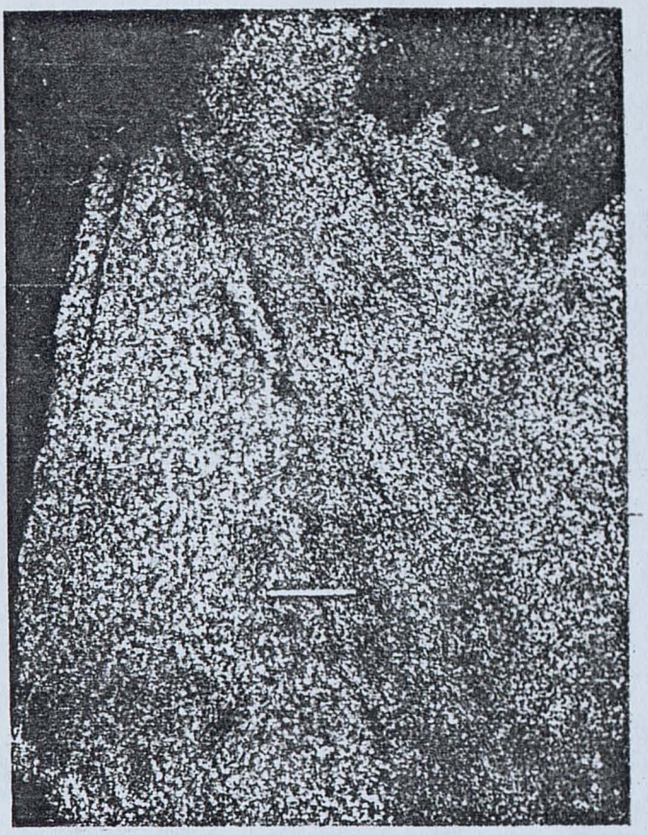


Figure 26

Figure 27

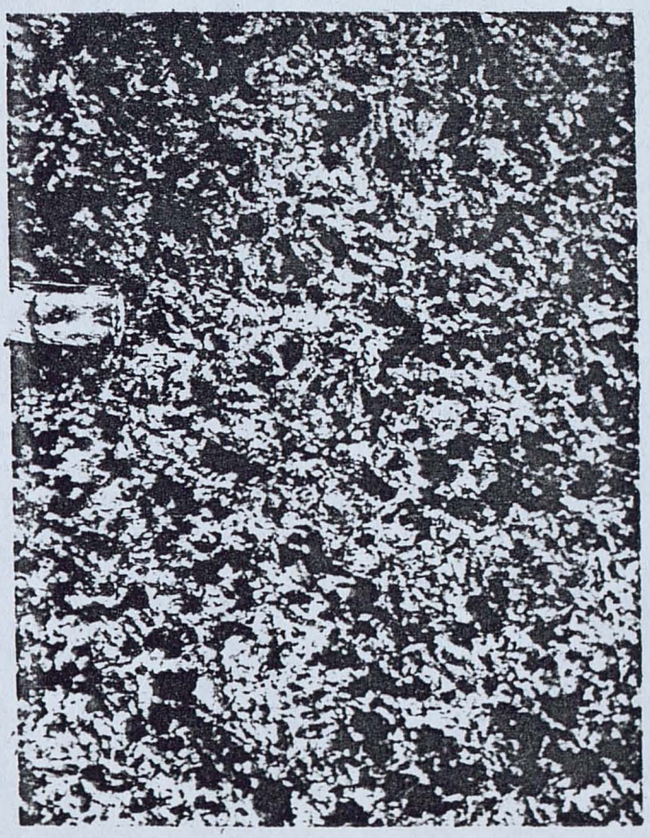


Figure 28. 59-13-26-1C: Modal layering in Partridge River troctolite.

Figure 29. 59-13-26-1C: Detail of Figure 28 showing abrupt change from troctolite to picrite, rock is a troctolite then an anorthositic troctolite a few meters stratigraphically above the picrite.

Figure 30. 59-12-7-2A: Medium- to coarse-grained olivine-gabbro to gabbro of Powerline gabbro; plagioclase is light-colored mineral; scale in cm.

Figure 31. 59-12-19-1A: Medium- to coarse-grained gabbro with high content (10%) of oxides of Powerline gabbro; plagioclase is light-colored and minerals exhibiting medium to high relief are oxides.

Figure 28

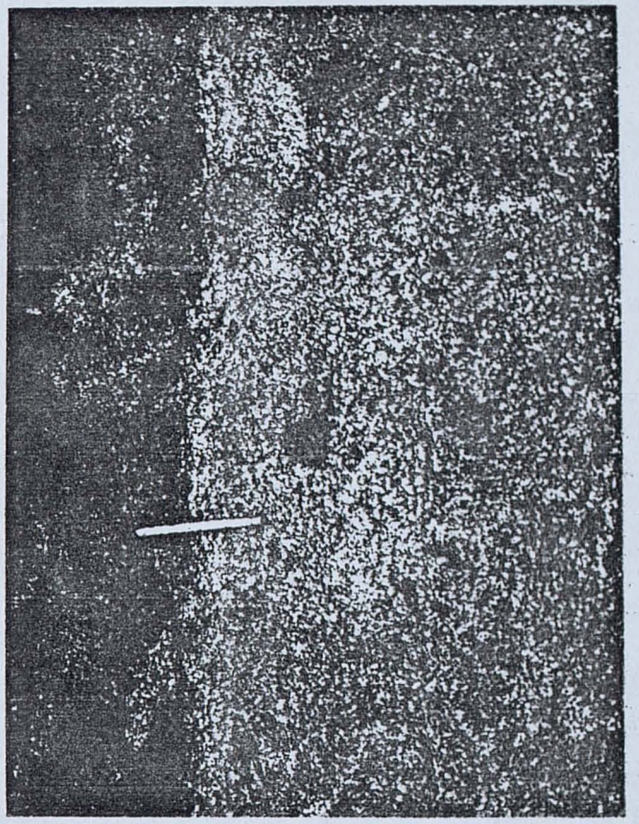


Figure 29

Figure 30

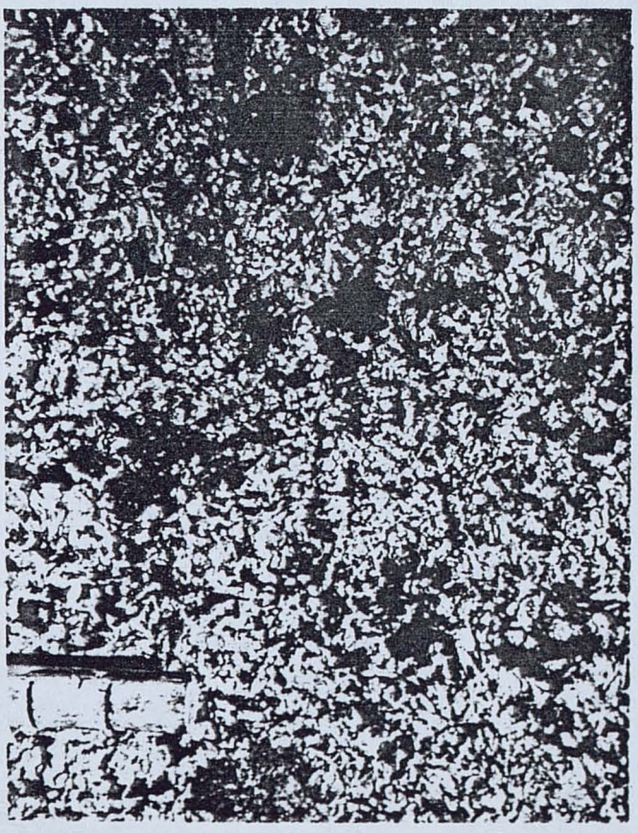


Figure 31

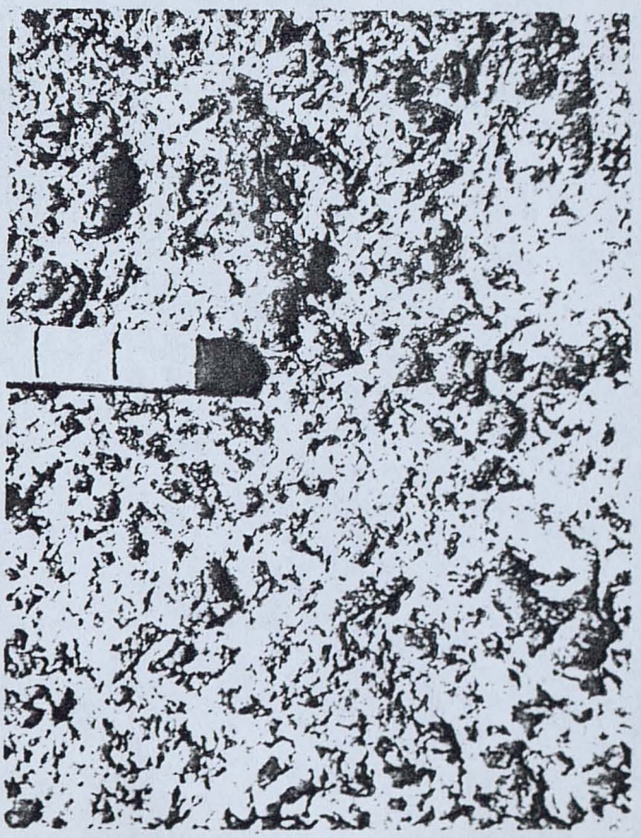


Figure 32. 62-10-30-97A: Detail of medium-grained anorthositic troctolite of flow-layered troctolite (tf); plagioclase is light-colored mineral; scale in cm.

Figure 33. 62-10-29-10D: Layering found in flow-layered troctolite; note small anorthositic inclusion or segregation near pencil.

Figure 34. 62-10-19-54B: Diabasic dike in undivided anorthositic gabbro (agu).

Figure 35. 59-12-7-1AB: Detail of contact between diabasic dike (top of photograph) and Powerline gabbro.

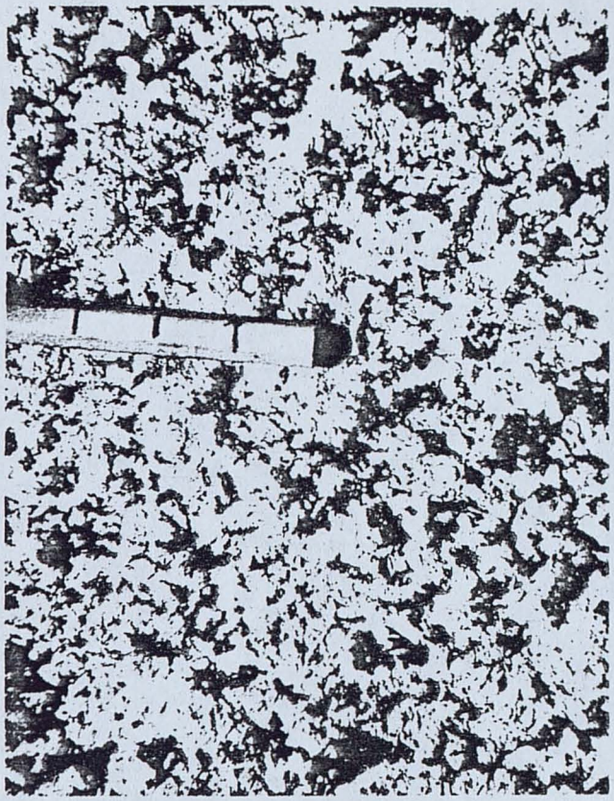
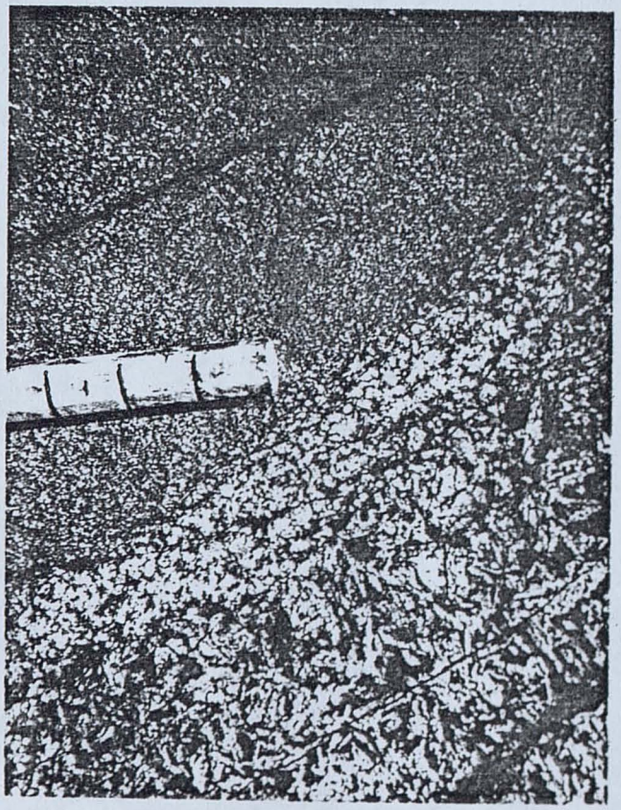


Figure 32

Figure 33

Figure 34

Figure 35



APPENDIX II

PART 2

Appendix II

Part II

The photomicrographs included in this appendix provide a permanent record of the thin sections examined in this study for: 1) grain size measurements (Figs. 4 and 5; Table 1, Appendix II, Pt. 3); 2) modal analyses (Figs. 6-12; Table 2, Appendix II, Pt.3) and 3) electron microprobe analyses (Fig. 15; Table 3, Appendix II, Pt. 3).

The photomicrographs were made on a Zeiss ultraphot microscope with a 93 mm lens. Four polaroid photographs were made of each thin section in partially crossed polarized light. In the assembled mosaic photomicrograph the bar scale = 2.5 mm. The photomicrographs are assembled in the order of the traverse along Minnesota Highway #1 (Fig.1). Additional photomicrographs not on the traverse as listed below are also included.

In the modal analyses six (6) minerals and one (1) intergrowth were identified:

1) Olivine (Ol) characterized by high relief (appears to stand up higher than other surrounding minerals), high birefringence, and subhedral (bordered by one or two crystal faces) to rounded or irregularly shaped grains. Olivine is commonly highly fractured and the fractures are irregular in nature. See photomicrographs of samples 59-10-31-1Aa and 62-11-25-55A for identified grains.

2) Plagioclase (Pl)--characterized by low relief (appears to be much lower than surrounding minerals such as olivine and clinopyroxene), low birefringence (white to gray), and tabular or lathy grains. The grains are commonly subhedral and lath-like, but irregularly shaped grains are also found. However, even the irregularly shaped grains are generally tabular or lath shaped. Individual plagioclase grains are commonly half white and half gray or exhibit alternating white and gray zones. This is the result of twinning in a single grain. See photomicrographs of samples 59-10-31-1Aa and 62-11-25-55A for identified grains.

3) Clinopyroxene (Cpx)--characterized by moderate relief (greater than plagioclase and slightly less than olivine), moderate birefringence, fractures of approximately right angles, and narrow linear zones of black opaque minerals which were exsolved during the cooling of the rock from the molten state. Occasionally these exsolved zones are so dense that they make the grain appear to be nearly opaque (See 62-11-25-55A). Grains are rarely subhedral (59-10-31-1Aa) and most commonly are interstitial to plagioclase, where they occupy triangular shaped spaces between plagioclase grains or form partial rims around olivine grains (62-11-25-55A).

4) Orthopyroxene--characterized by moderate relief similar to that exhibited by clinopyroxene, low birefringence which is slightly higher than that exhibited by plagioclase, fractures of approximately right angles and a pale pinkish color. Orthopyroxene which is relatively rare in these rocks, occurs as small interstitial grains which are usually closely associated with olivine. Occasionally the orthopyroxene occurs as narrow reaction rims around olivine grains. See sample 62-11-25-19A for identified grains. The orthopyroxene is almost impossible to distinguish from clinopyroxene in the photomicrographs and was identified using a polarizing microscope for the modal analyses.

5) Opaque minerals (Opq)--this includes all oxide minerals such as ilmenite and magnetite and all sulfide minerals such as pyrrhotite, pentlandite and cubanite. These minerals are black in the photomicrographs. They form irregularly shaped interstitial grains in all the Duluth Complex rocks in the Hoyt Lakes--Kawishiwi are. See photomicrographs of samples 59-10-31-1Aa, 62-11-25-55A and 62-11-35-19A for identified grains.

6) Biotite (BiO)--characterized by low relief which is slightly higher than plagioclase, high birefringence, and a red-orange to yellow-orange color under a polarizing microscope that readily distingjishes it from all other minerals present in these rocks. It usually forms small interstitial grains and occasionally forms a rim around opaque minerals. See photomicrographs of samples 62-11-25-55! and 62-11-35-19A for identified grains.

7) Symplectite--this occurs as very fine lenticular (5-20 micrometers wide) intergrowths of plagioclase and orthopyroxene. Because of the small size of the intergrowths they are not designated on the photomicrographs.

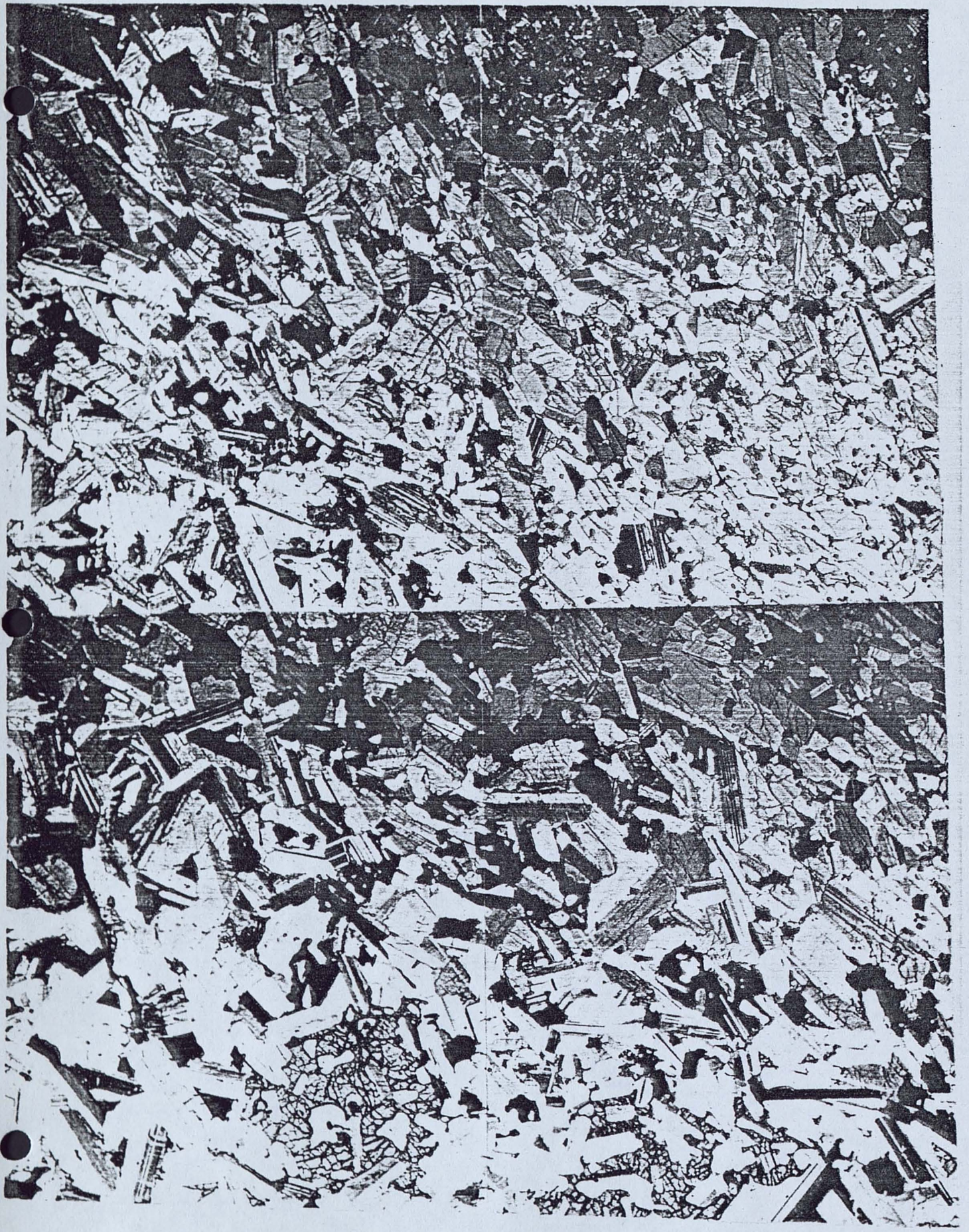
M6227A

M6227A (1)

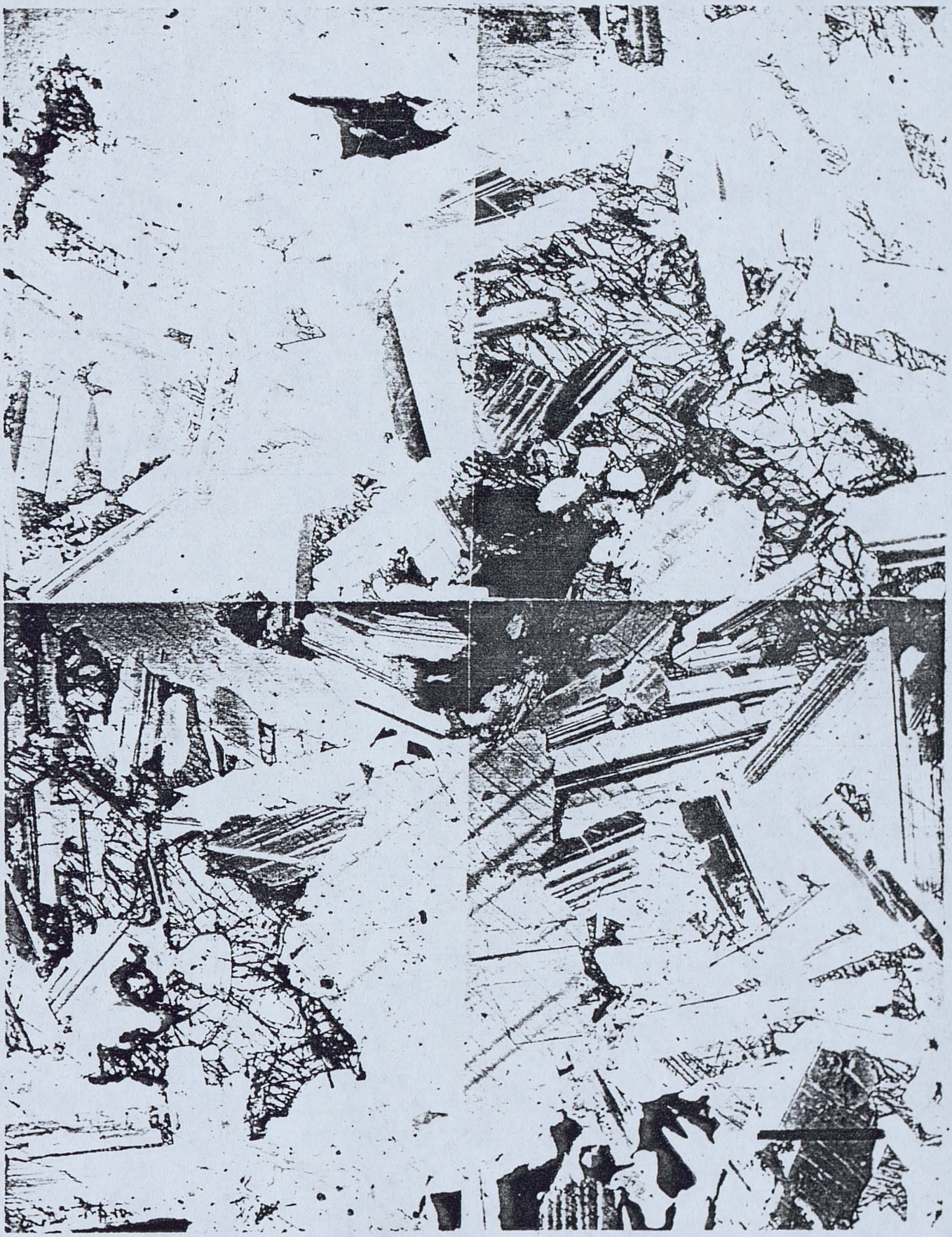
M6227A(2)

M6227

M6227

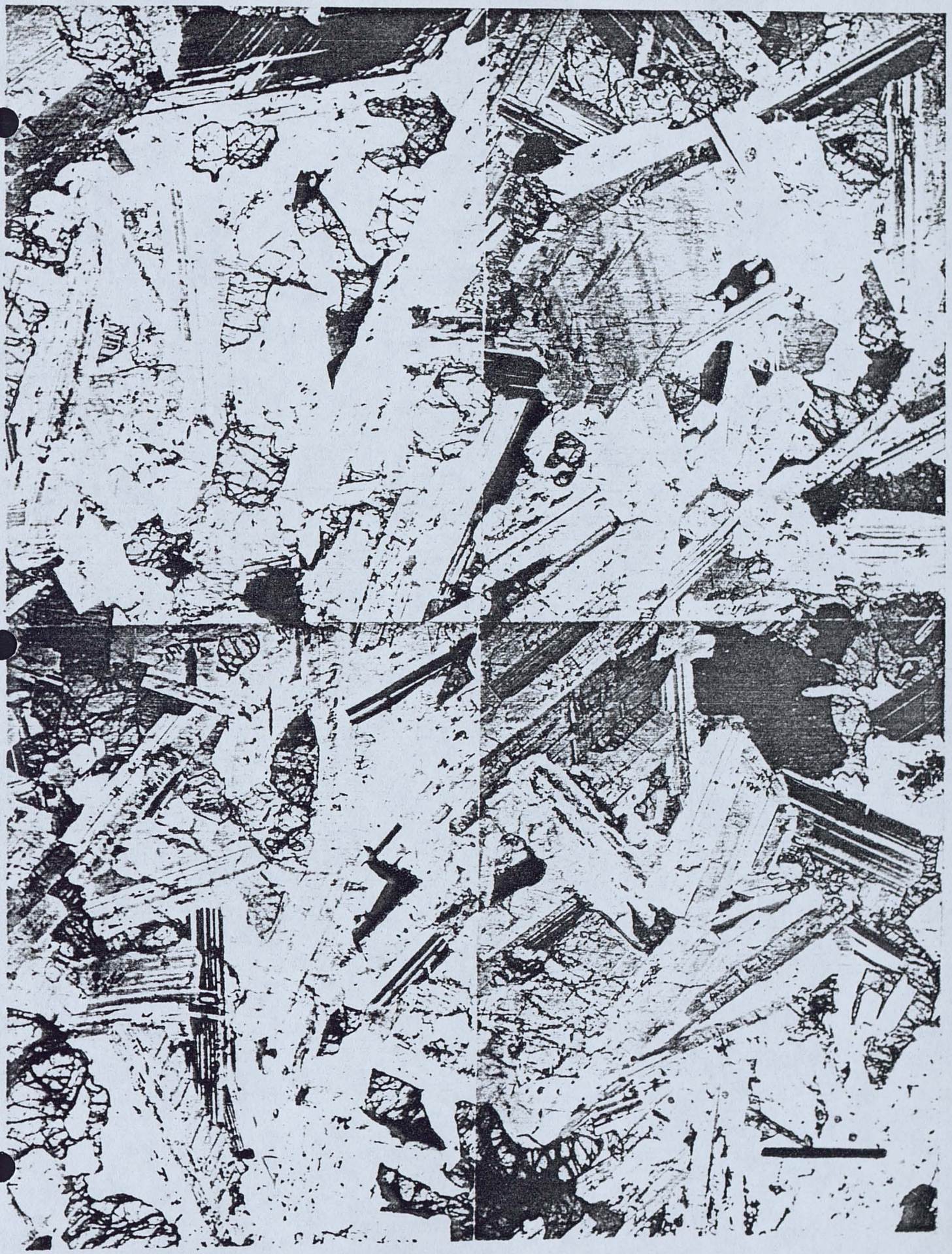


M6228



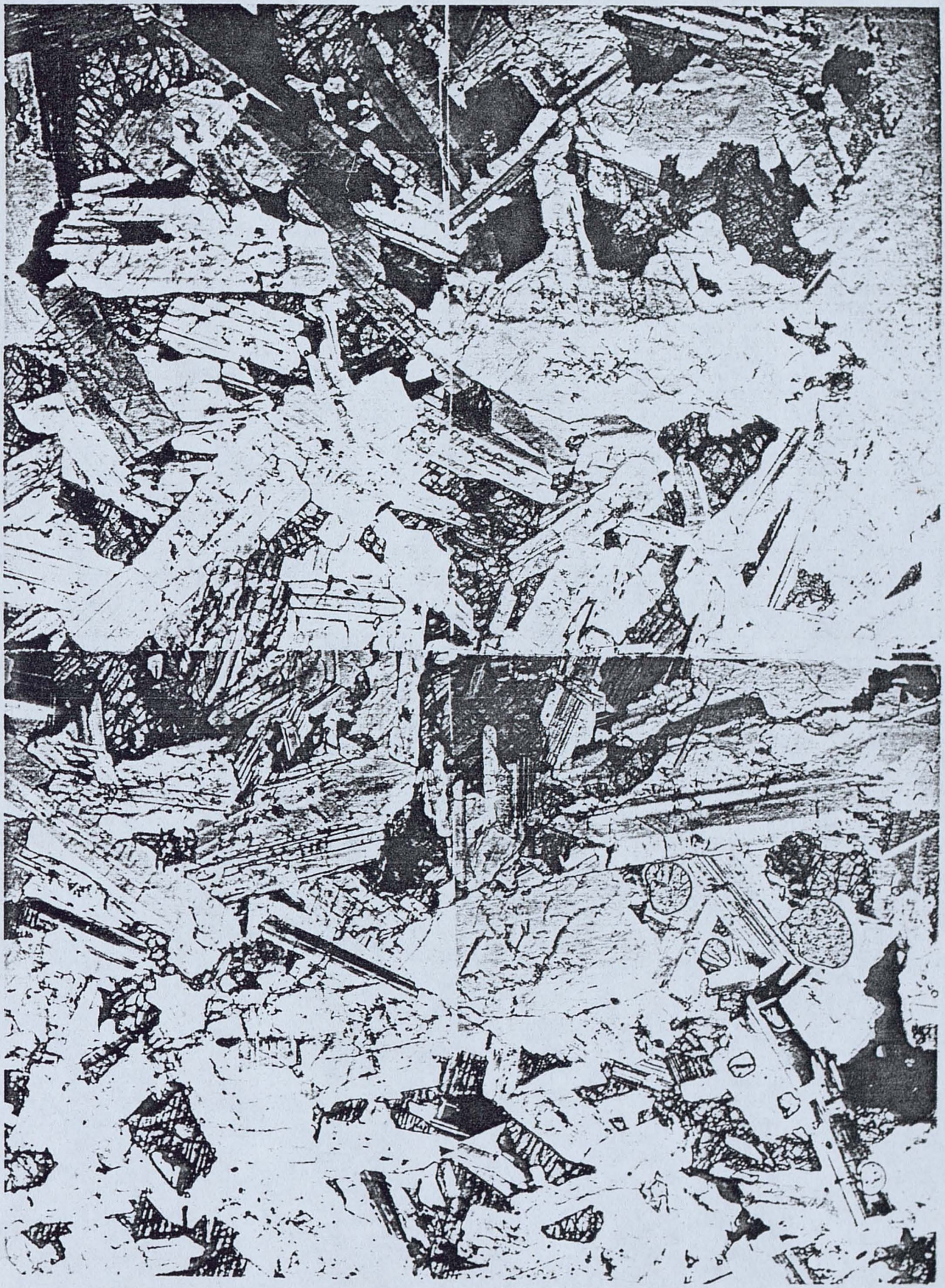
62-11-33-2A

61-11-3-2A

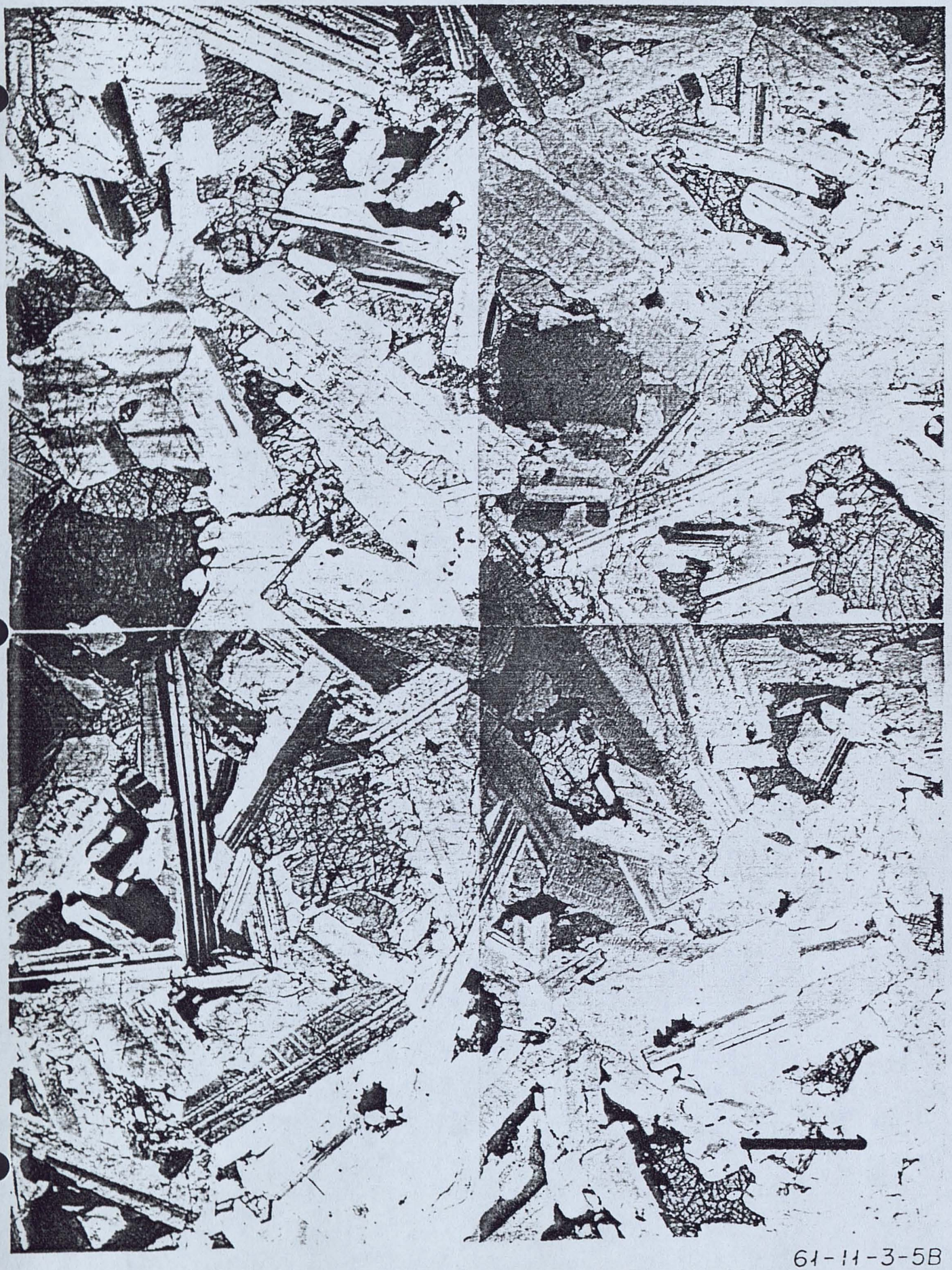


61-11-3-3A

M6225



61-11-3-4A



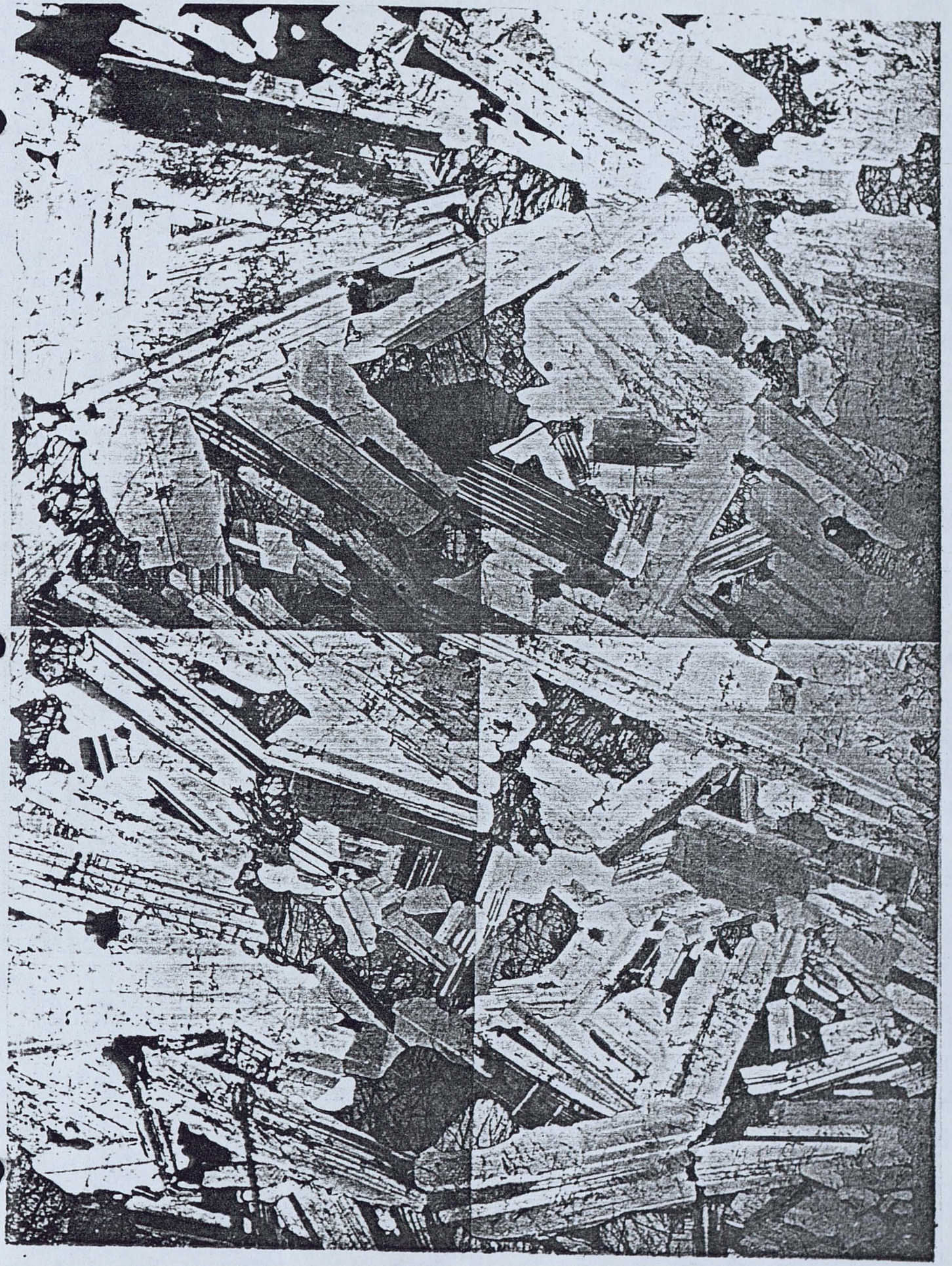
61-11-3-5B

61-11-3-6A

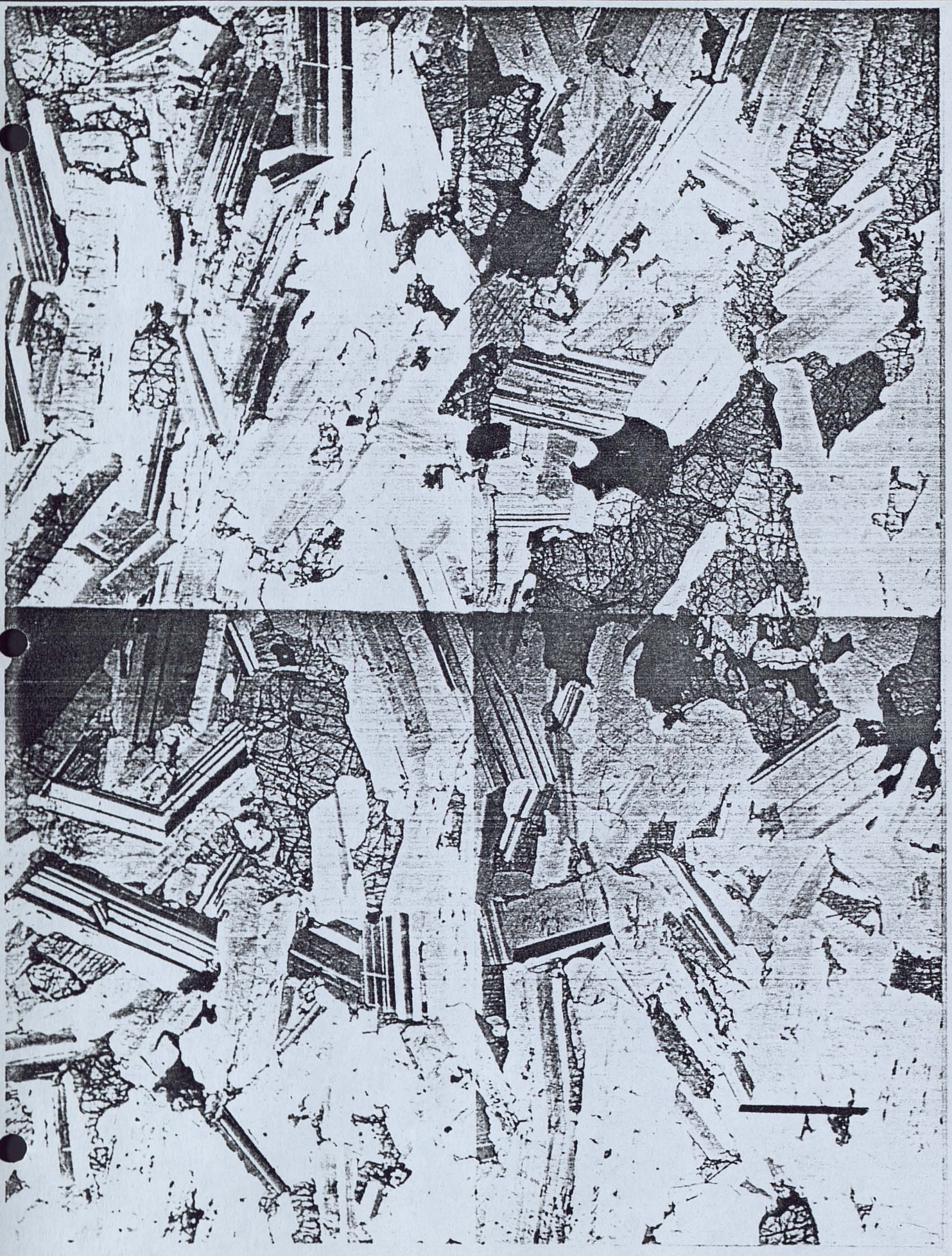
61-11-3-7A

M6222

61-11- 3-12A



61-11-3-13A



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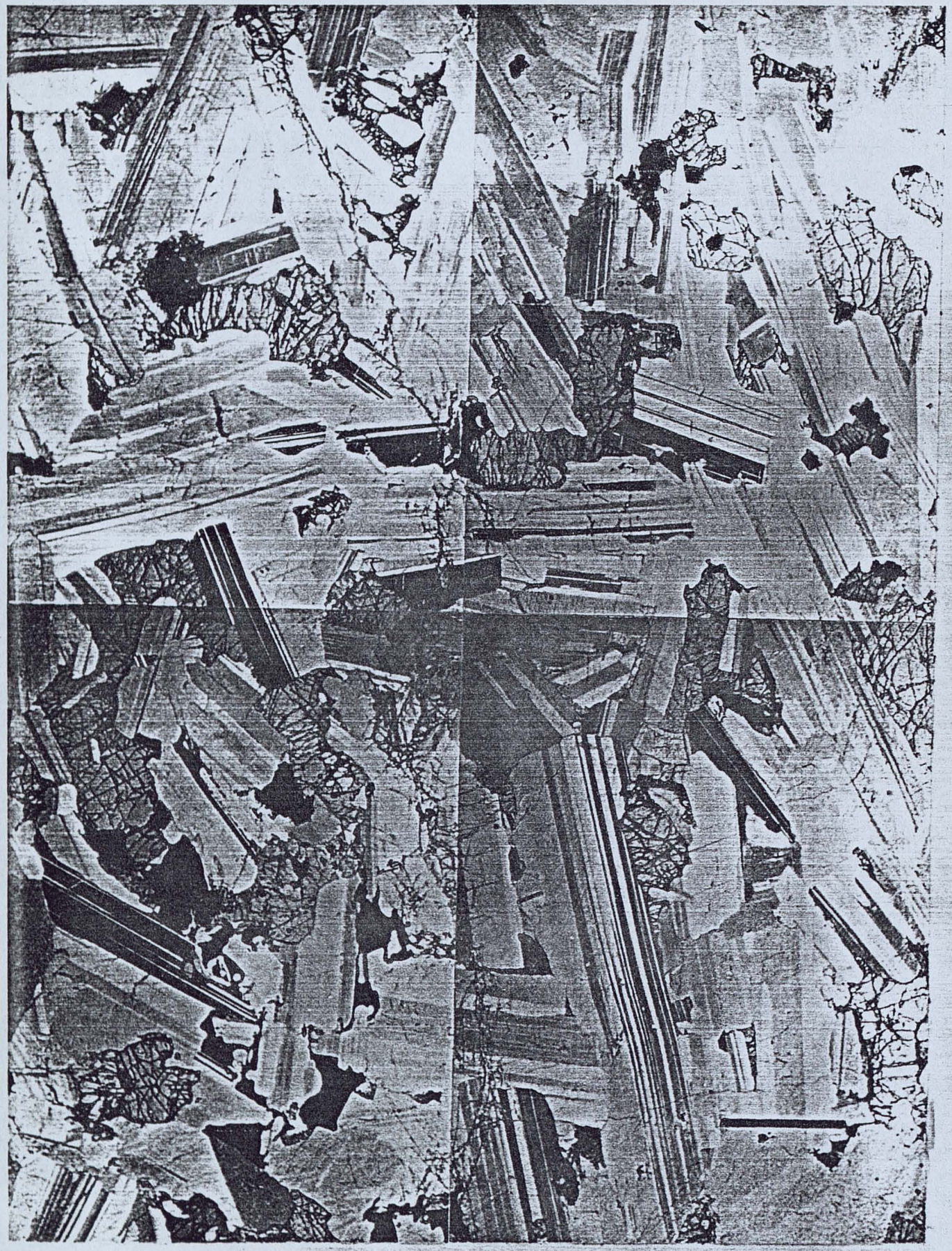
M6221

61-11-11-2B

61-11-11-3B



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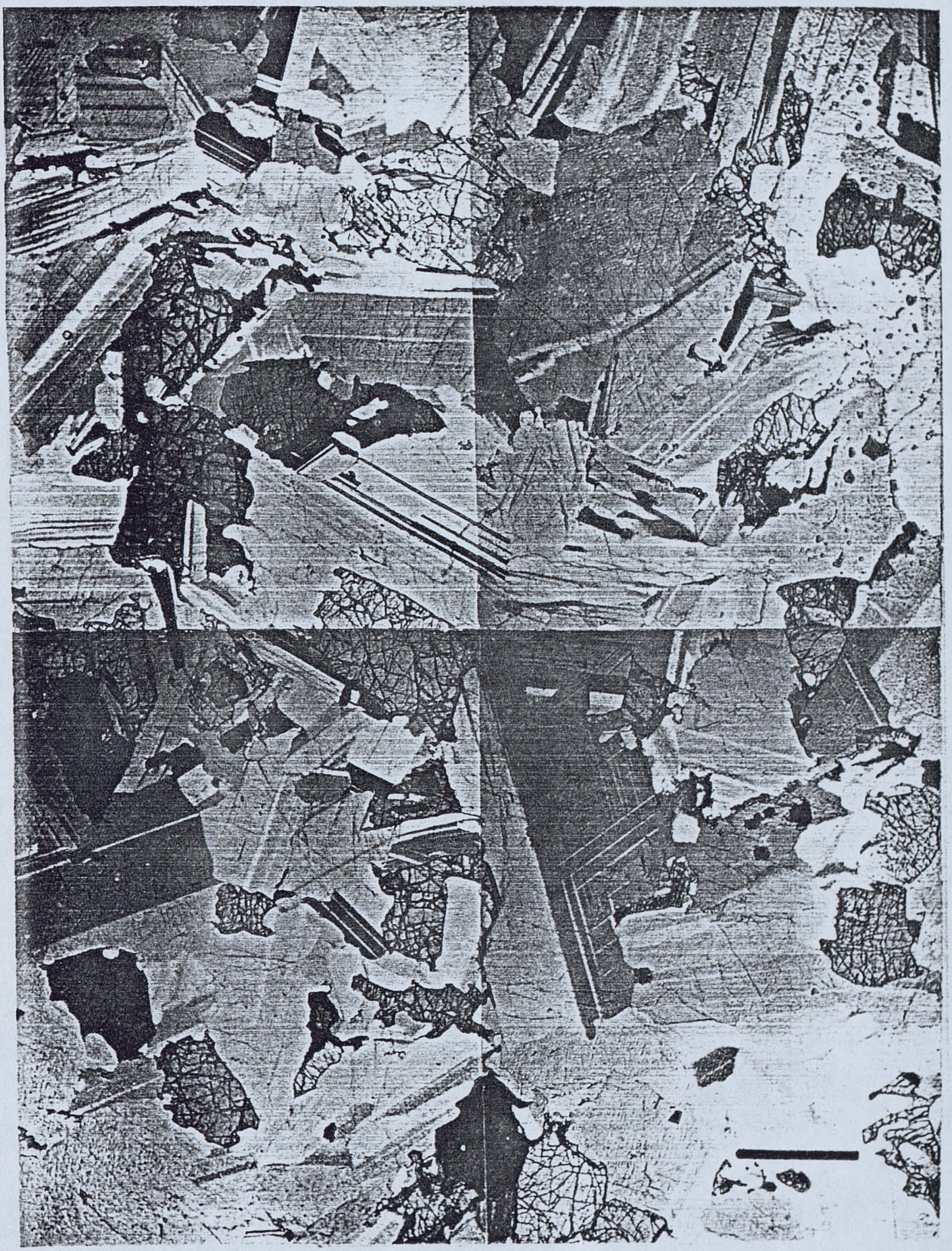

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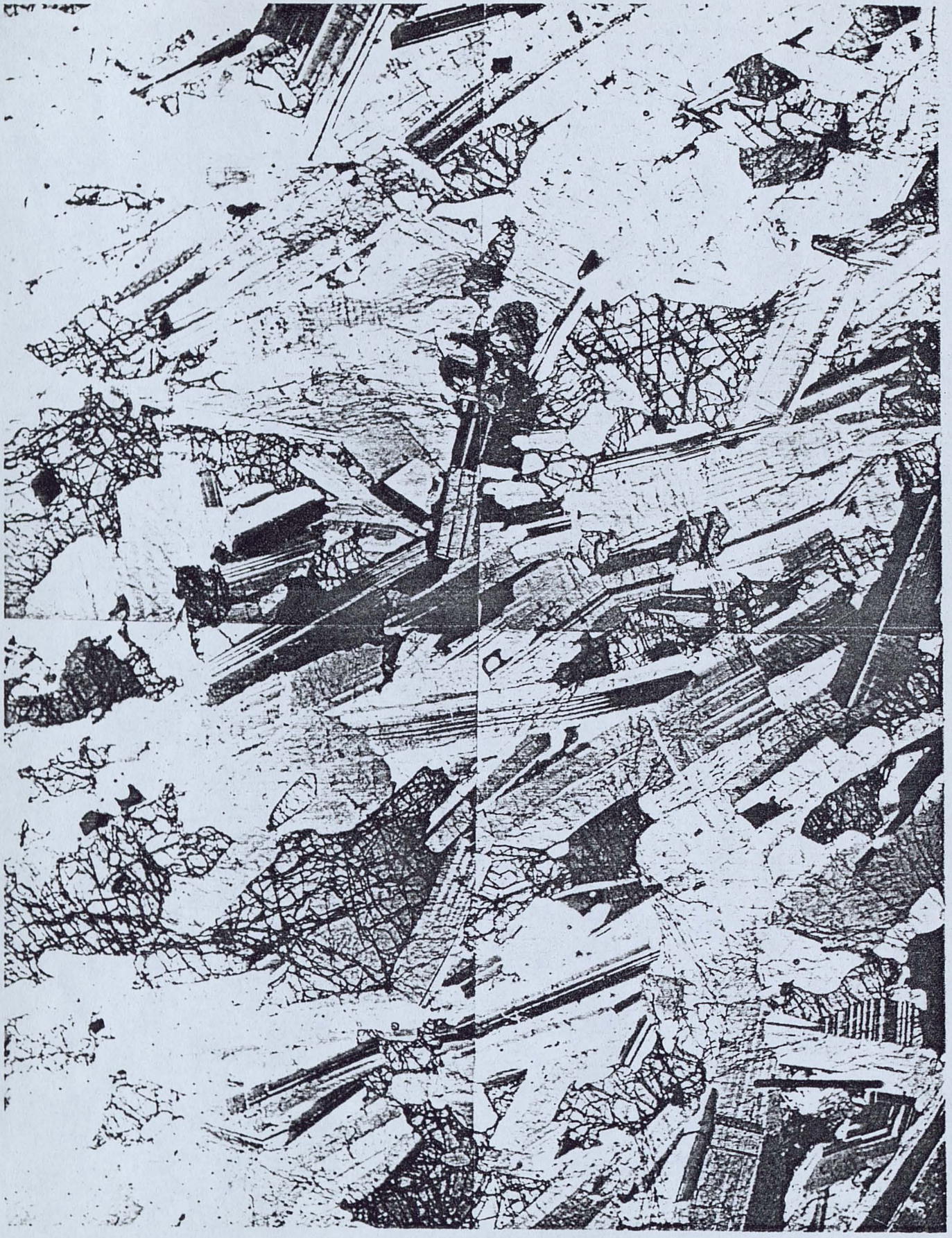

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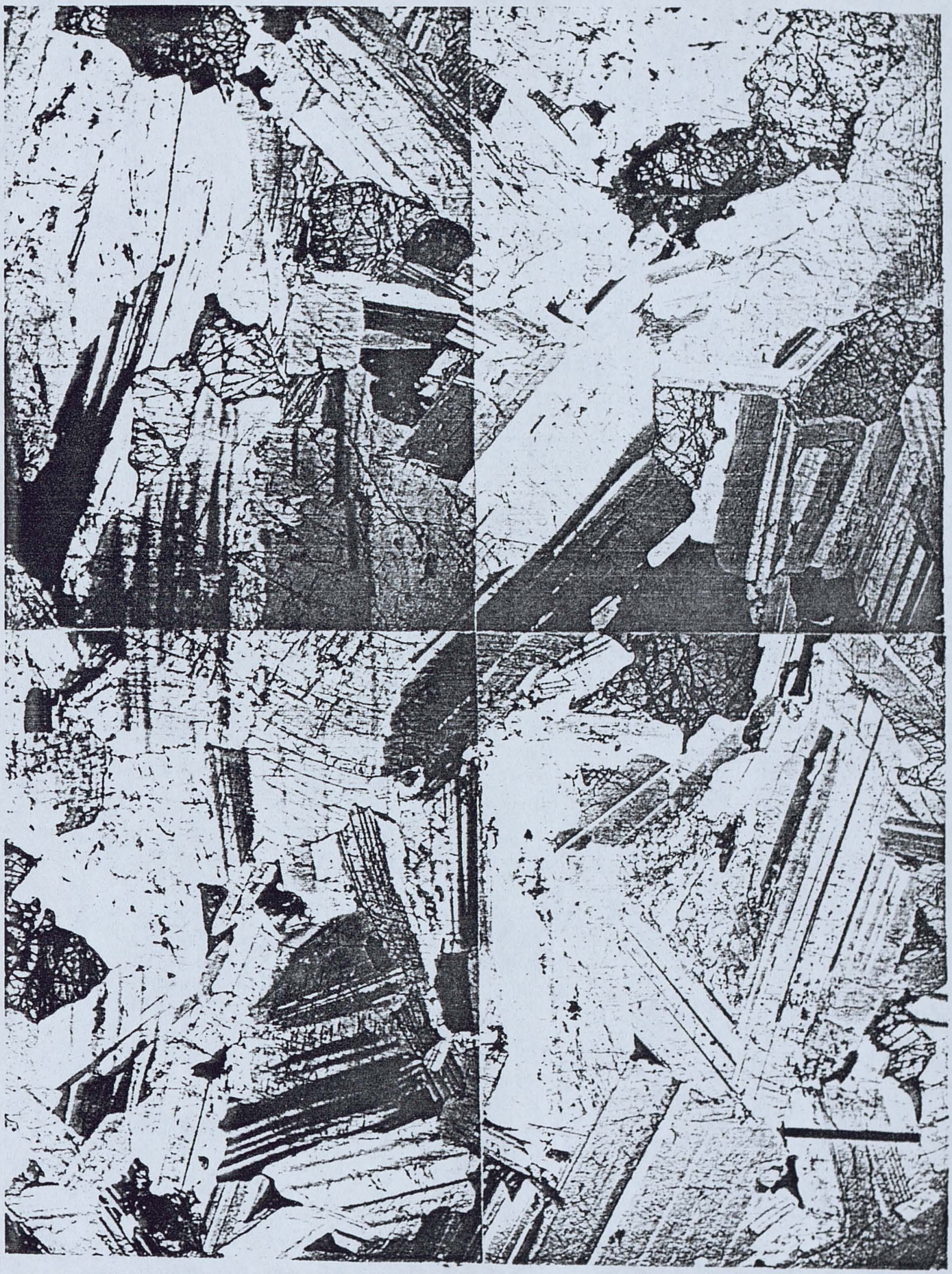

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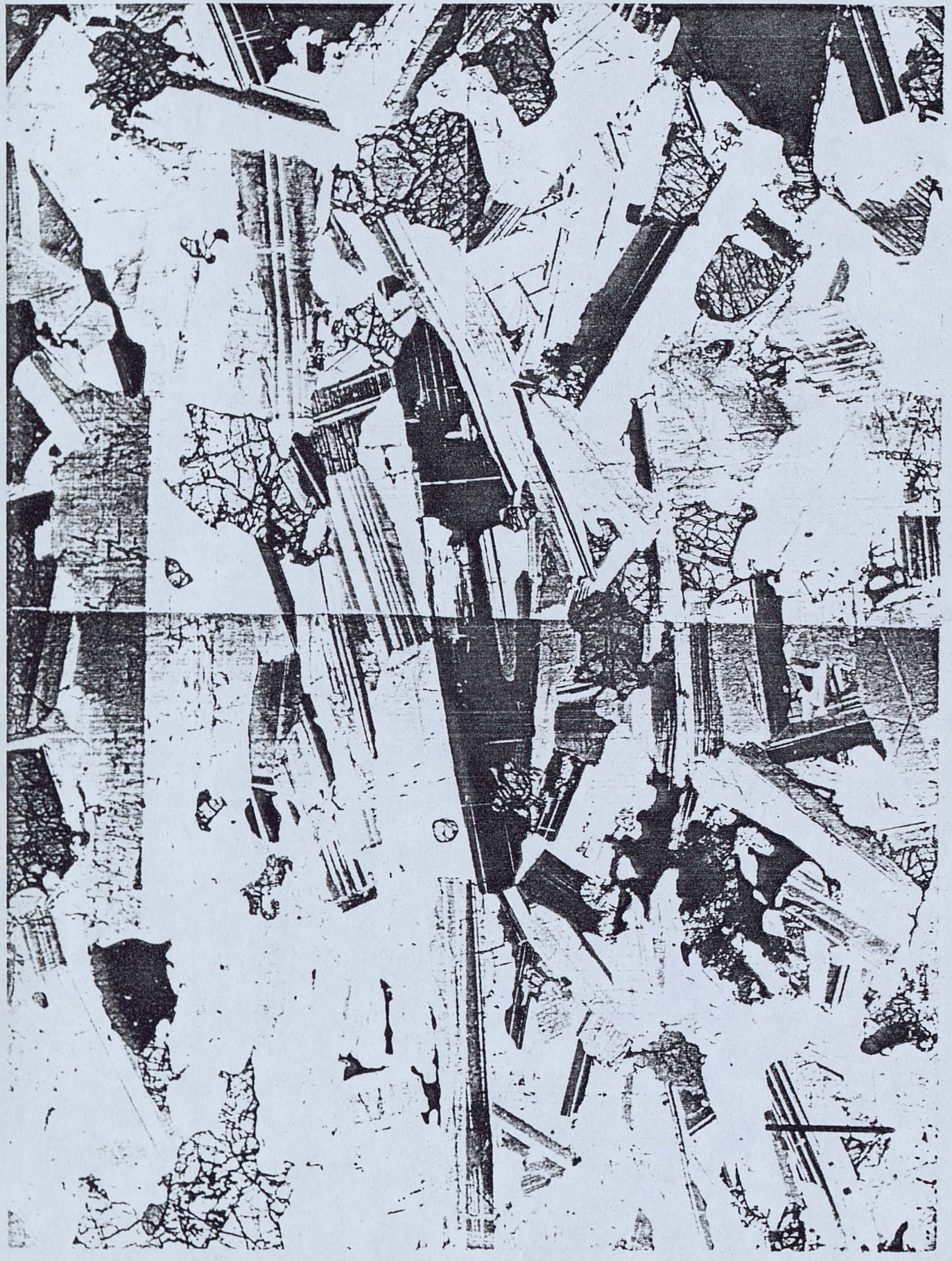

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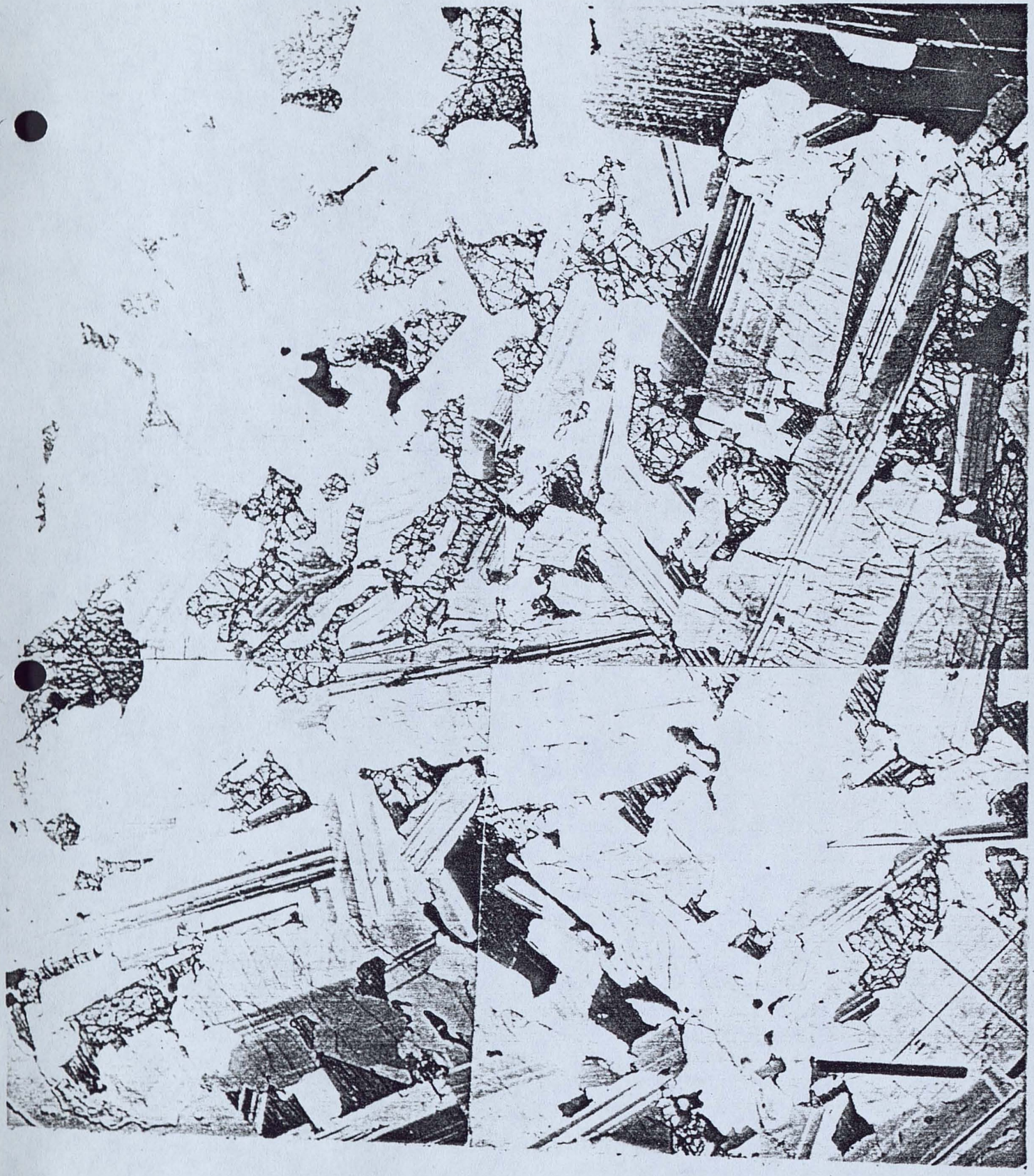
61-11-13-4Ao



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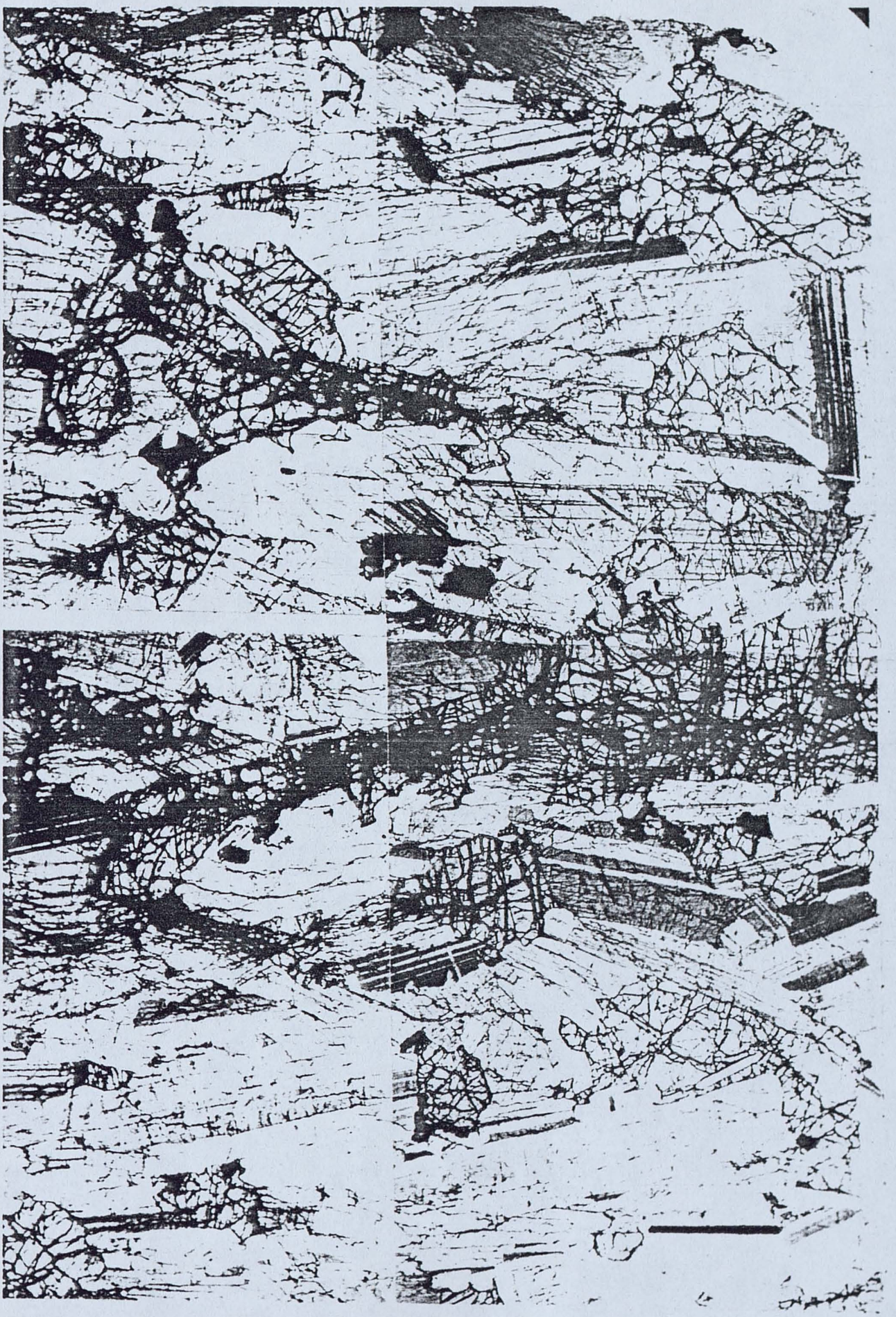

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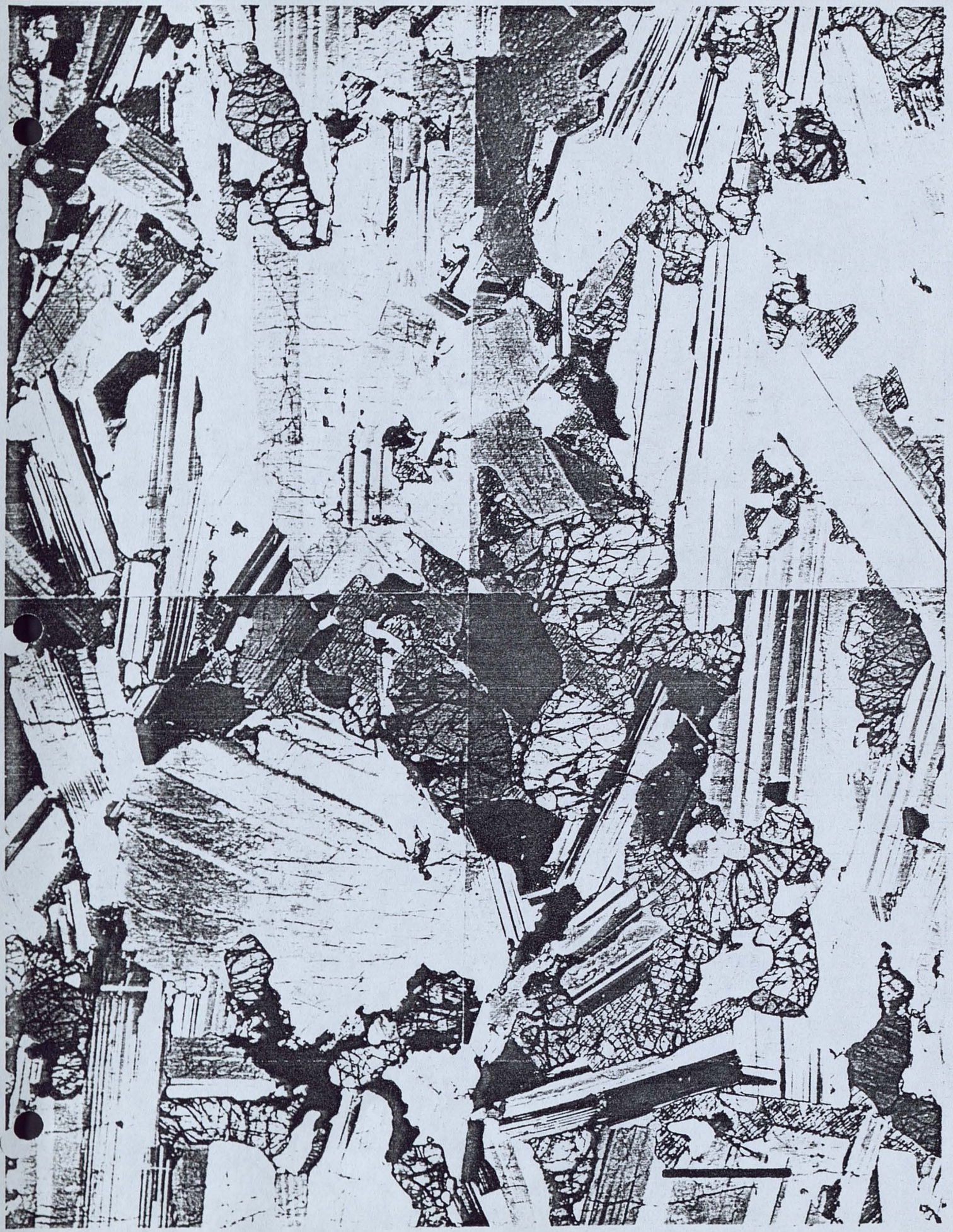
61-10-18-10Ab

61-10-18-10Ac



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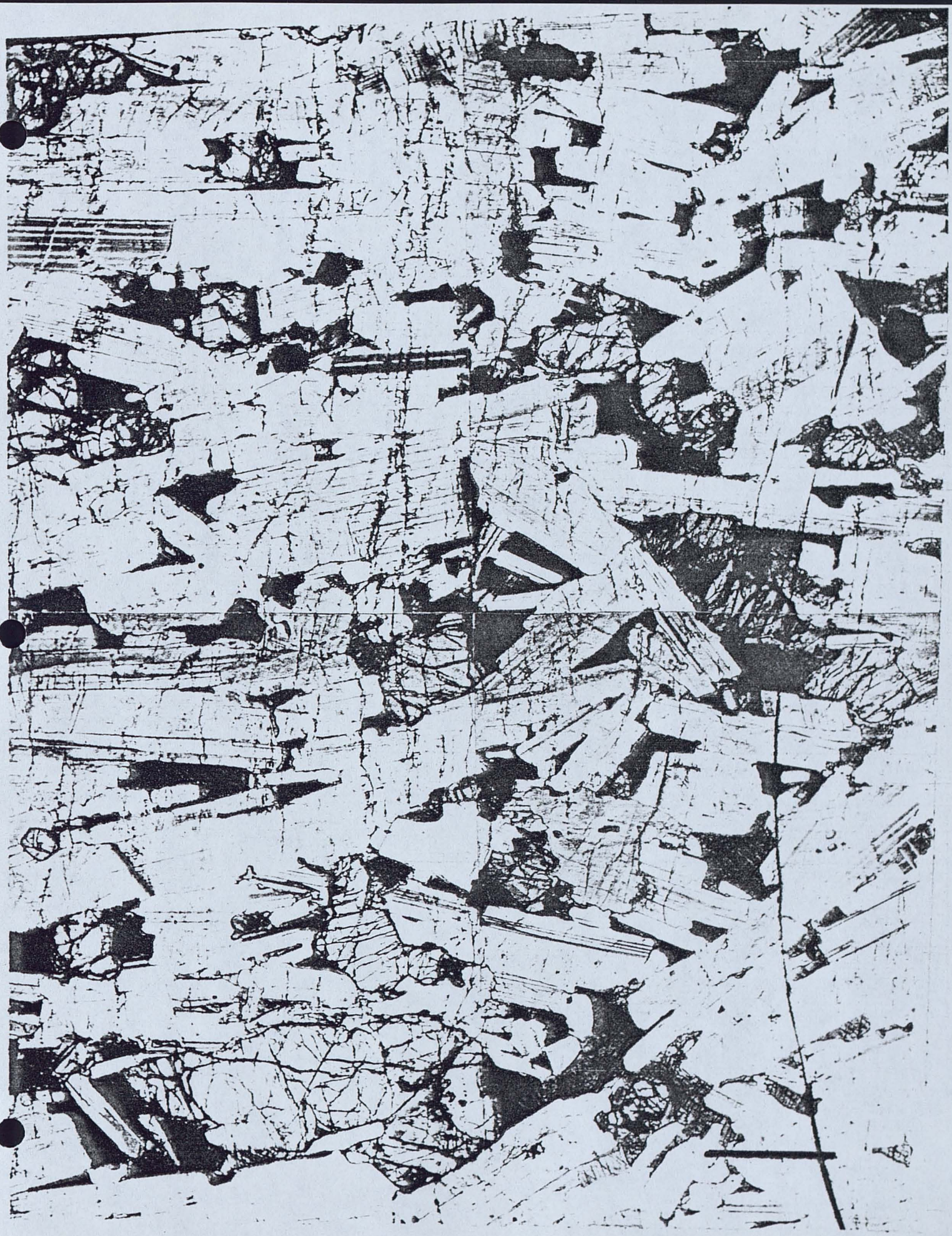

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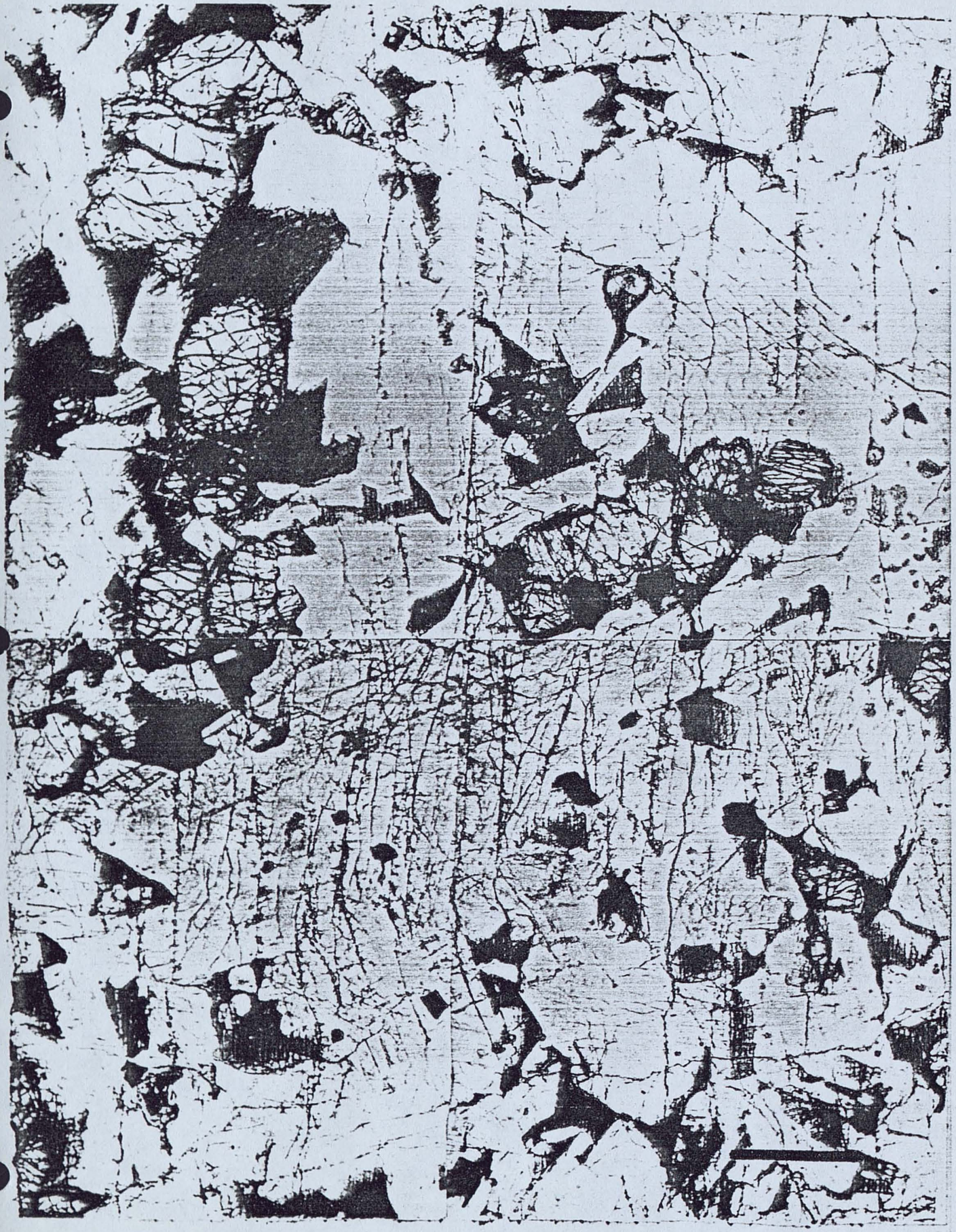

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61-10-18-19A

61-10-18-8Aa

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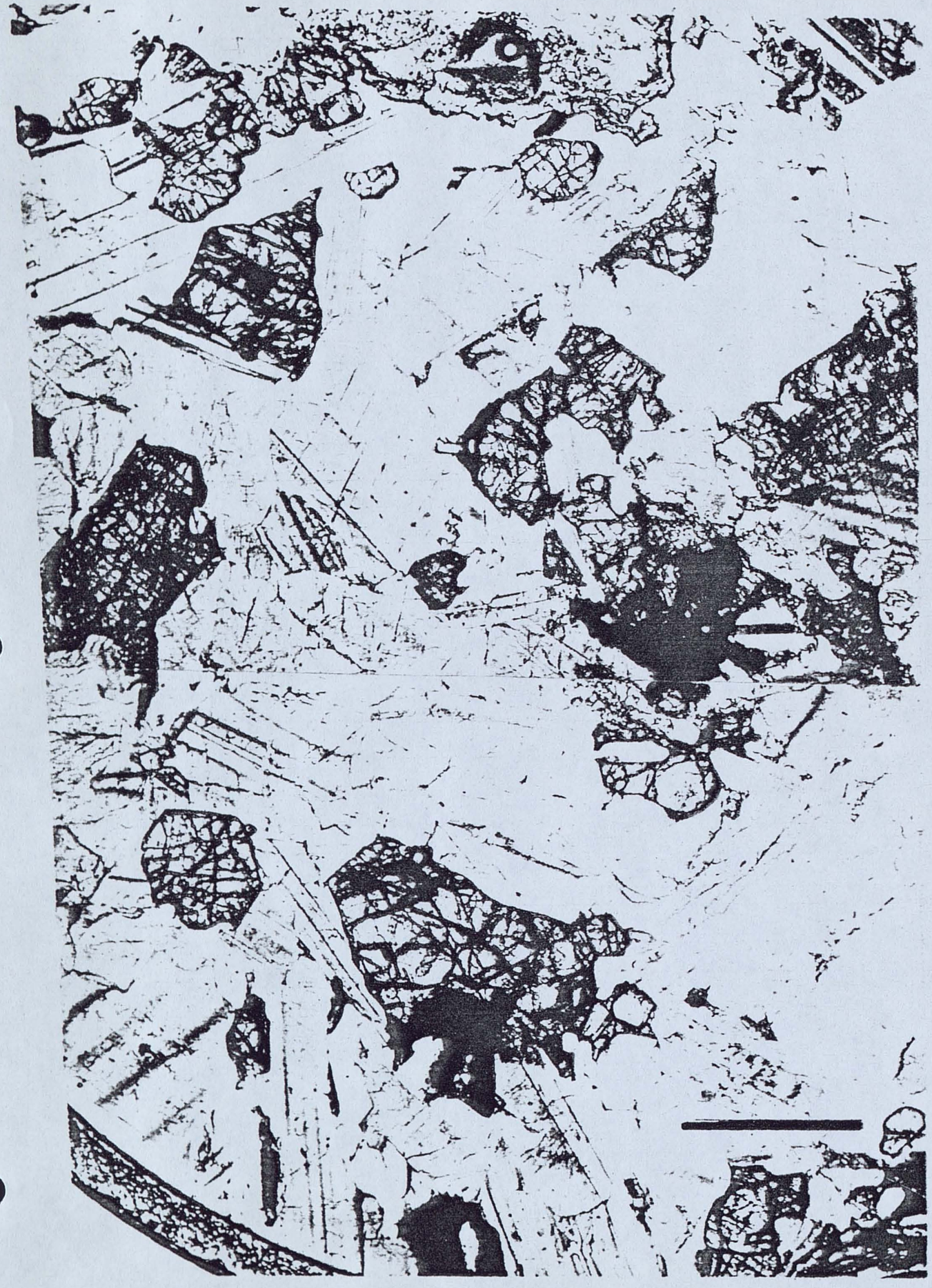

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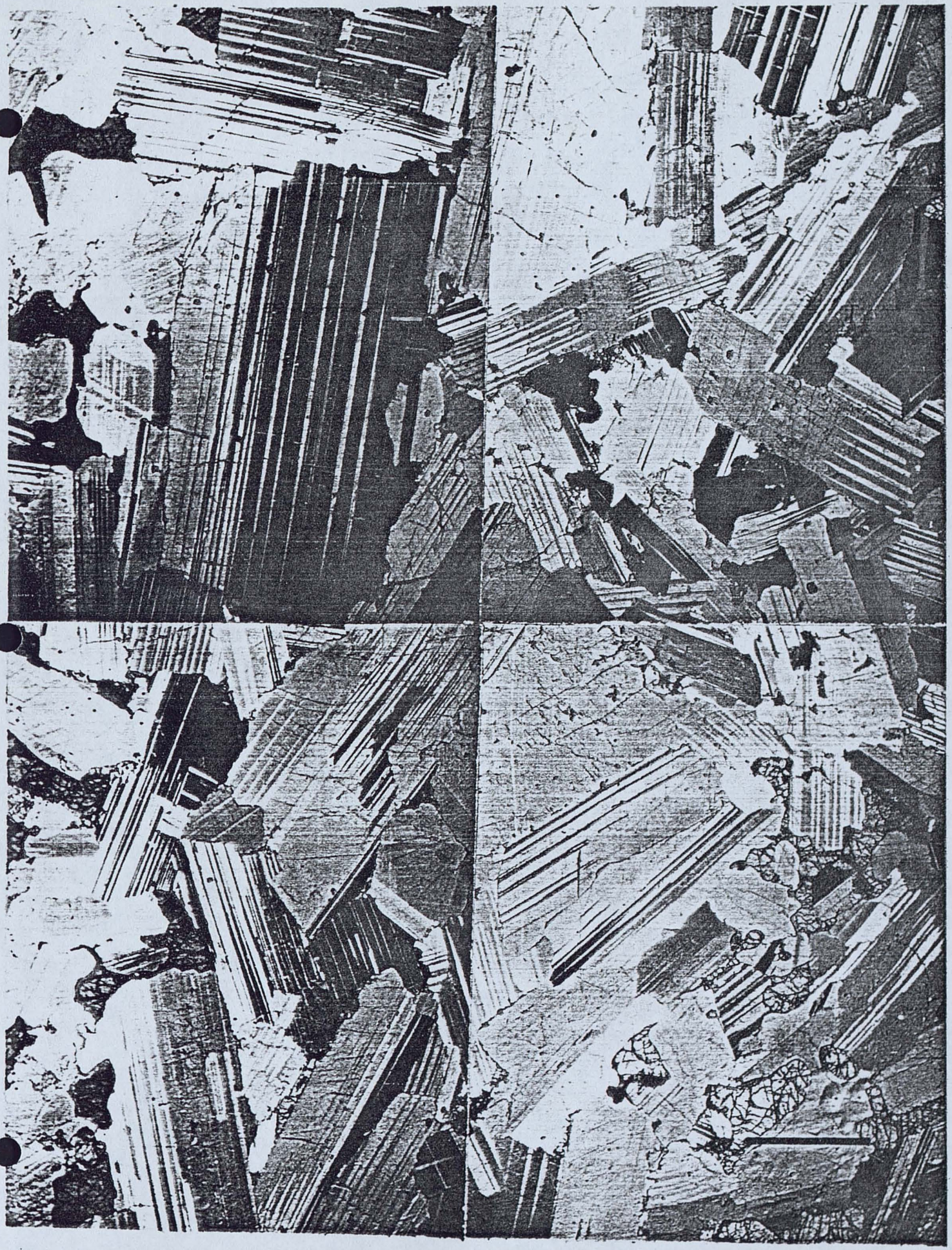

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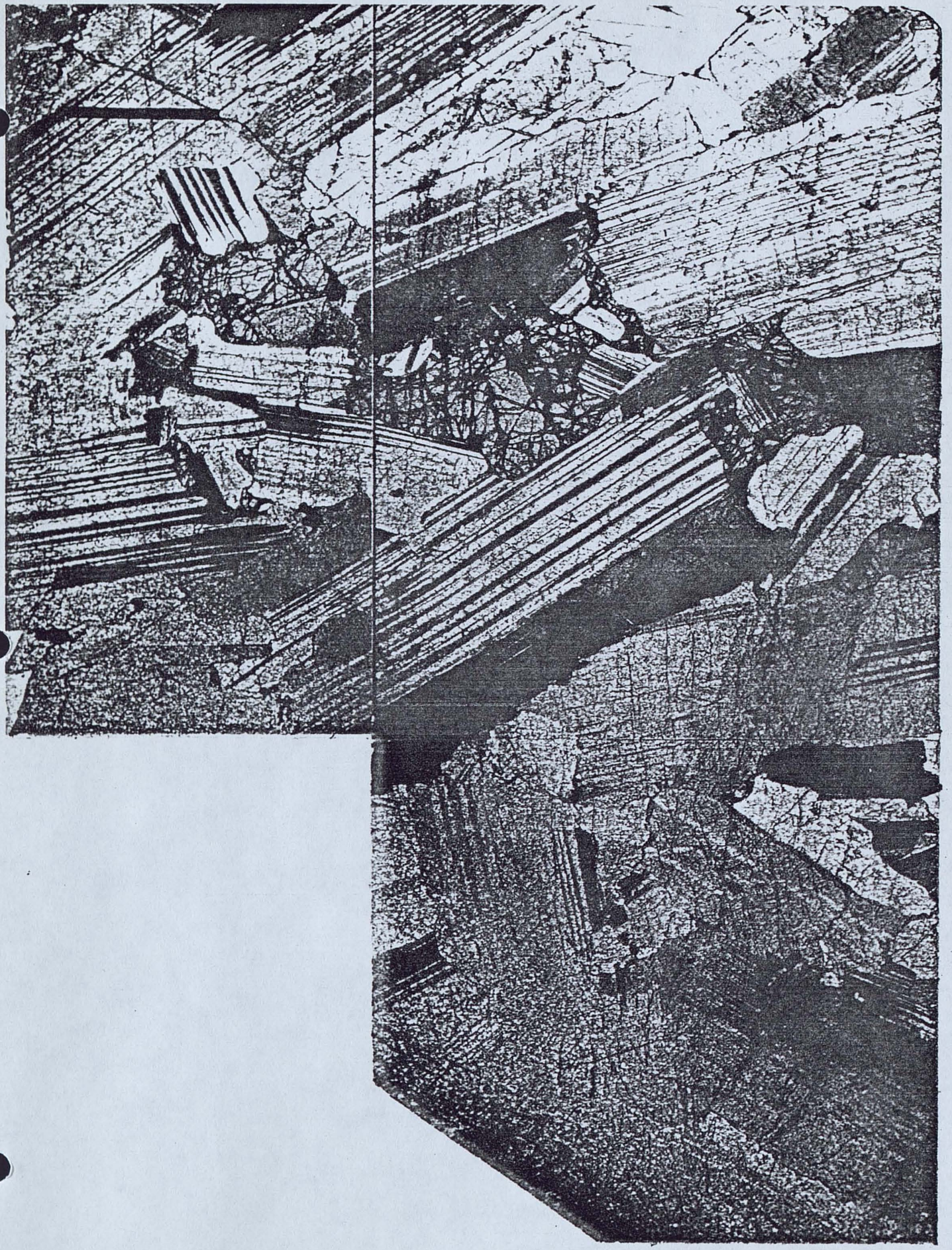

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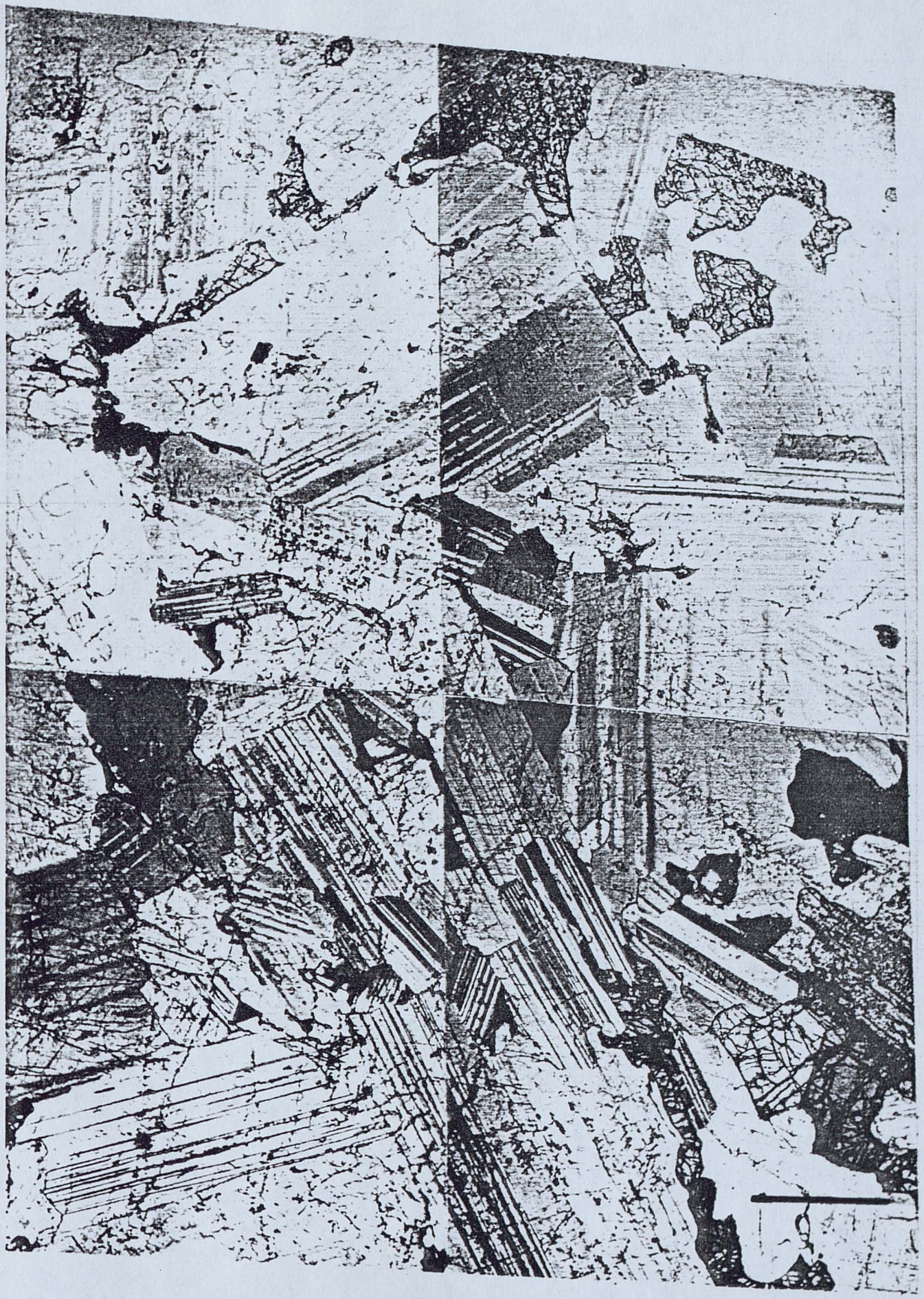

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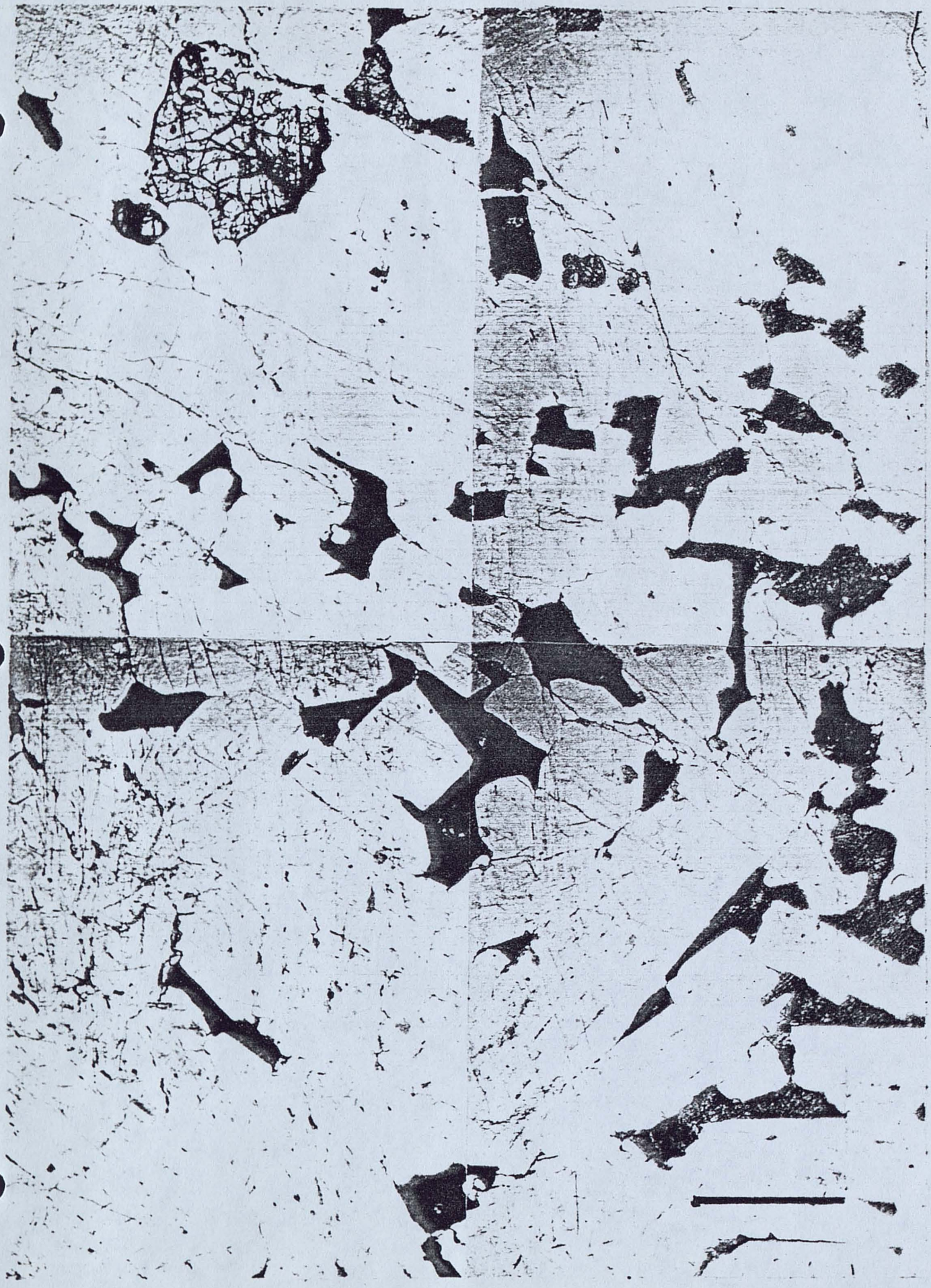

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61-10-19-9A

61-10-19-8A

59-10-31-1Aa

59-10-31-1Ab

59-10-31-1Ac

61-10-18-7Aa

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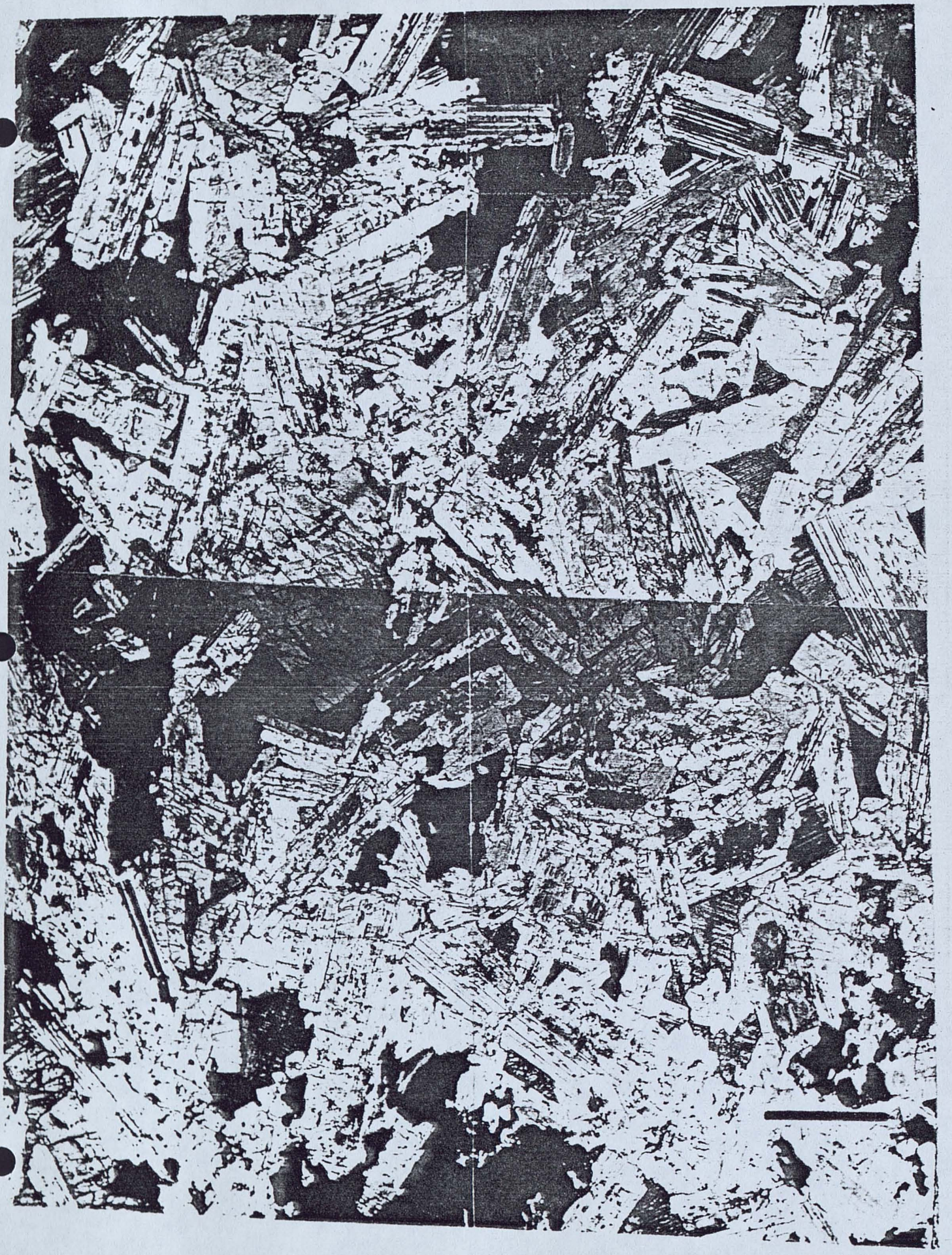
61-10-19-6Aa



M6233

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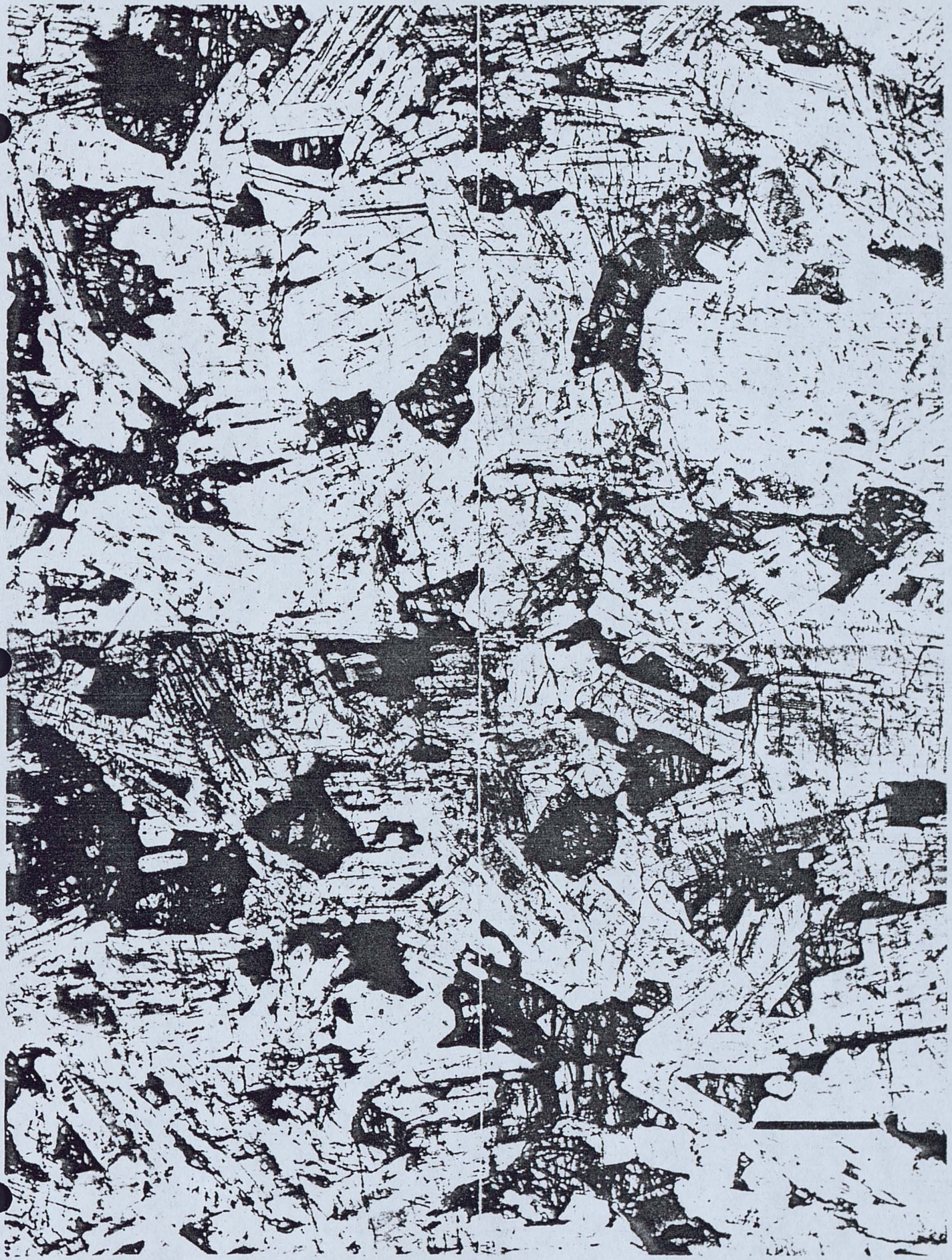
62-11-35-19A



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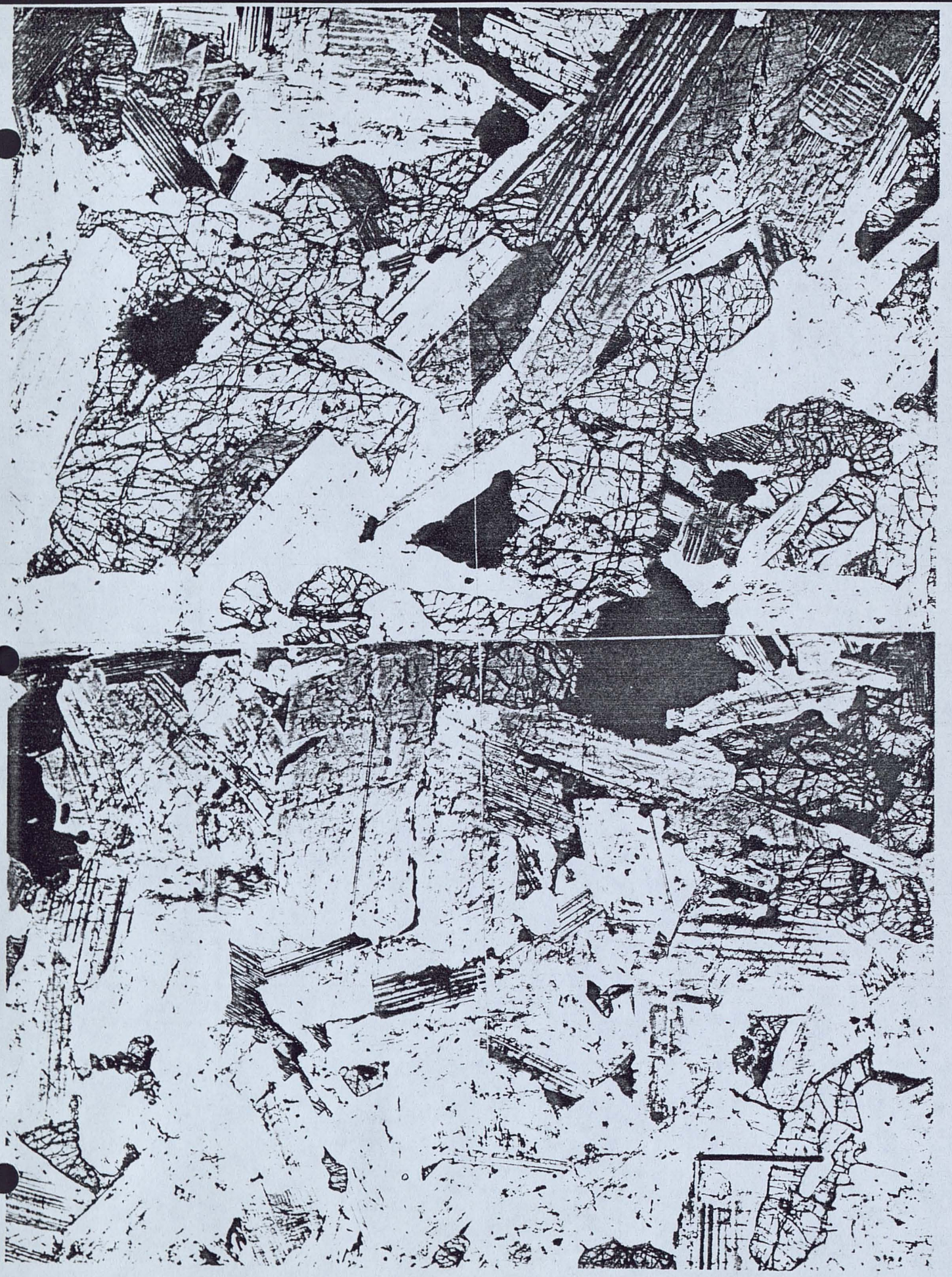
62-11-35-34C

62-10-19-74

62-10-19-74A

62-10-19-74B



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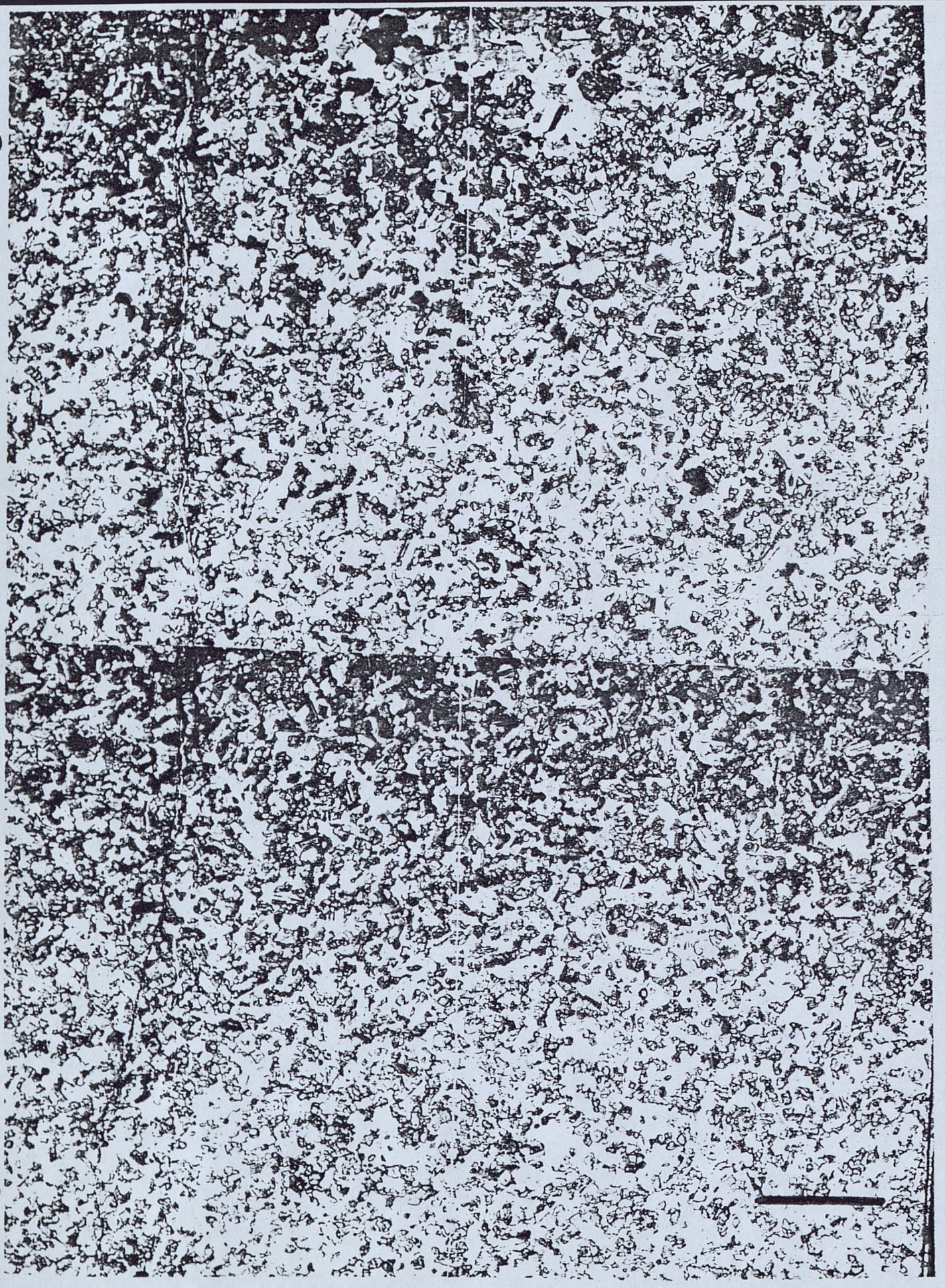
62-11-24-13A



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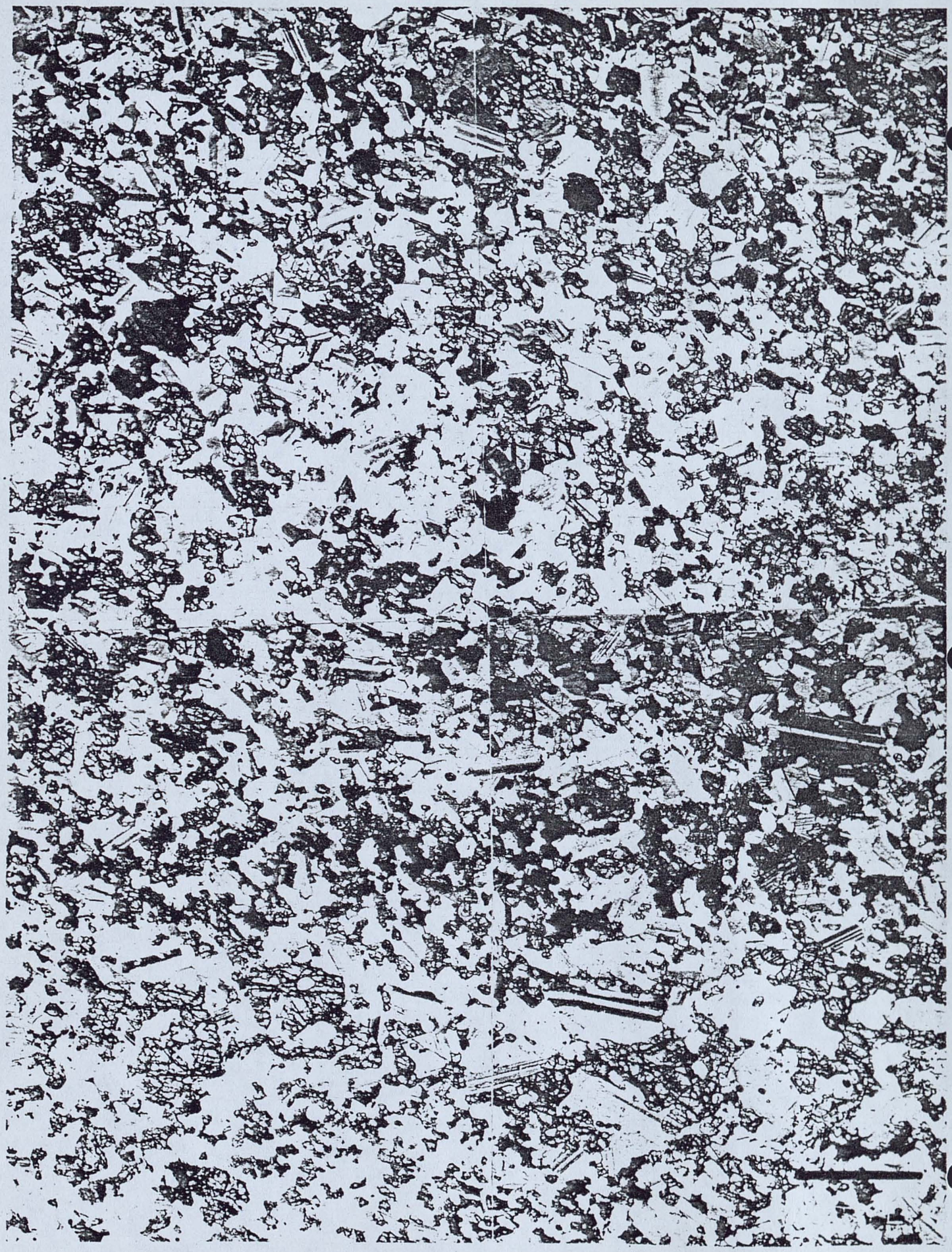
62-11-24-12B



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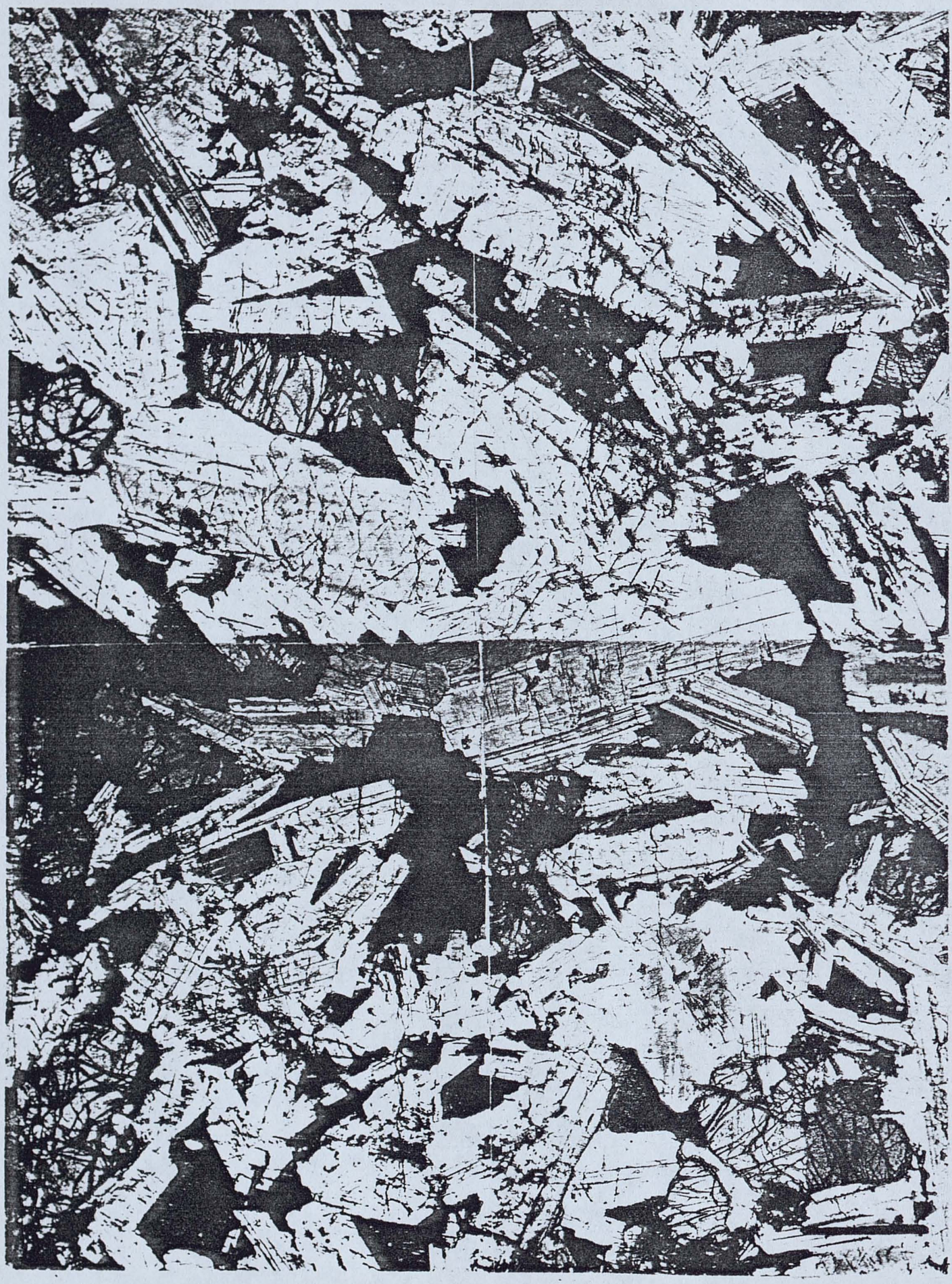

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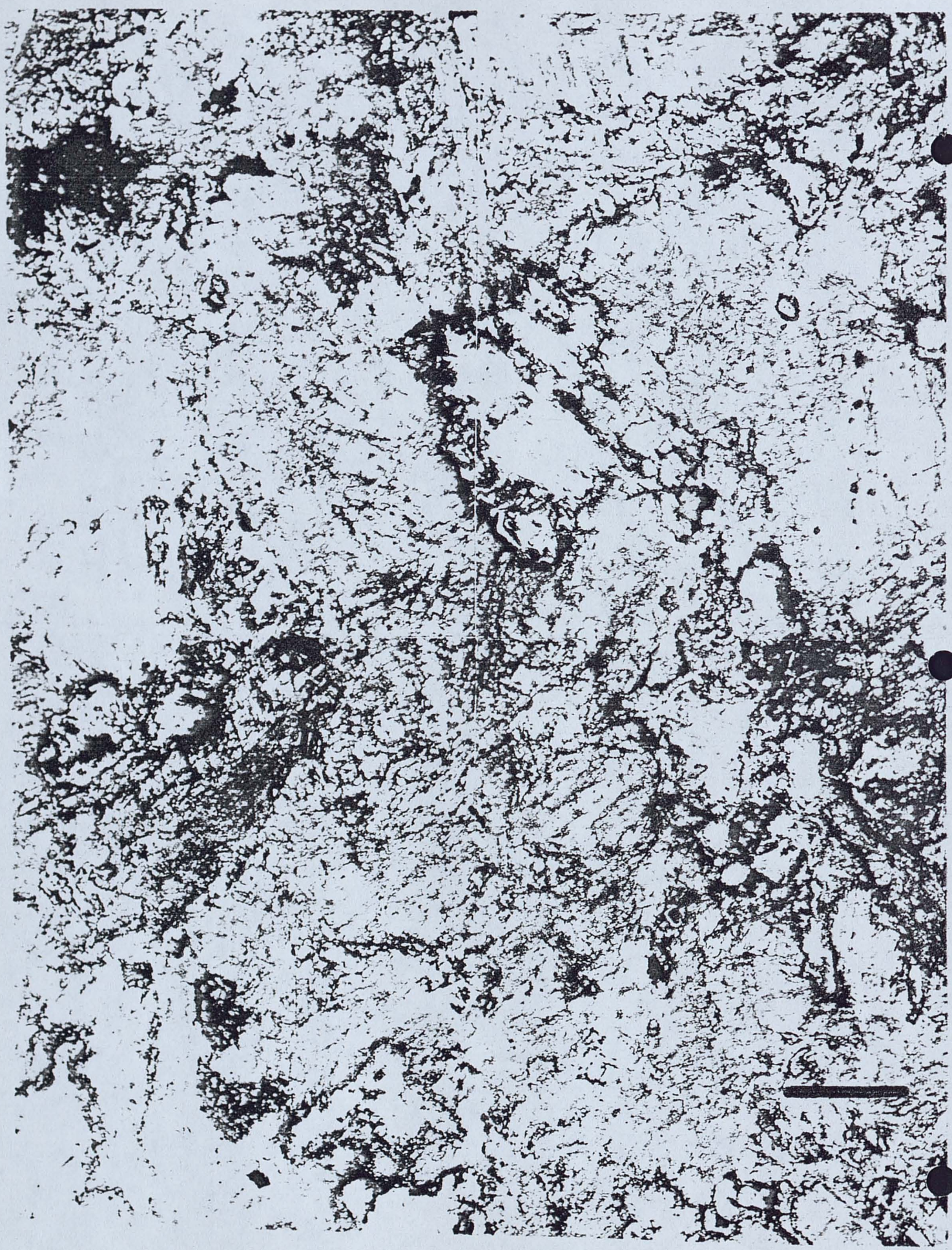
62-11-25-59A

62-11-25-123A

62-11-25-55A



62-11-25-90A

APPENDIX II

PART 3

Table 1. Grain size measurements of plagioclase in troctolitic-gabbroic series rocks from the Kawishiwi area.

Measurements were made by Keith Rosvold on the photomicrographs in Appendix 2, part 2. The data on width shows a normal distribution (Fig. 4). Length measurements show a wider dispersion due to errors associated with orientation of the thin sections relative to degree of preferred orientation of plagioclase in the rocks (Fig. 13).

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TABLE 1. PLAGIOCLASE GRAIN SIZE DATA (MM) HWY 1 TRAVERSE

SAMPLE	GRAIN	PHASE	LENGTH	WIDTH	AREA	LENGTH/WIDTH
611018			[illegible]	1.100000	7.040000000	[illegible]
611018			7.[illegible]	1.200000	8.520000000	5.916667
611018			4.[illegible]	.700000	3.430000000	7.[illegible]
611018			6. [illegible]	1.100000	6.000000000	5.454545
611018			3.[illegible]	.500000	1.700000000	6.[illegible]
611018			5.[illegible]	2.800000	16.520000000	2.107143
611018			4.700000	1.100000	5.170000000	4.272727
611018			6.500000	1.500000	9.750000000	4.333333
611018			3.700000	1.400000	5.180000000	2.642857
611018			2.[illegible]	.400000	1.000000000	5.250000
611018			1.200000	.300000	.360000000	4.000000
611018			2.300000	.800000	1.840000000	2.875000
611018			1.600000	.700000	1.120000000	2.285714
611018			4.700000	.100000	.470000000	* .4E+02
611018			2.300000	.500000	1.150000000	4.600000
611018			3.500000	.600000	2.100000000	5.833333
611018			1.700000	.400000	.680000000	4.250000
611018			4.100000	.700000	2.870000000	5.857143
611018			8.200000	1.400000	11.480000000	5.857143
611018			8.500000	1.700000	14.450000000	5.000000
611018			3.500000	1.100000	3.850000000	3.181818
611018			2.600000	1.200000	3.120000000	2.166667
611018			5.400000	.700000	4.000000000	8.285714
611018			4.000000	.600000	2.400000000	6.666667
611018			3.200000	.500000	1.600000000	6.400000
611018			3.400000	.900000	3.060000000	3.777778
611018			2.100000	.800000	1.680000000	2.625000
611018			4.700000	1.100000	5.170000000	4.272727
611018			3.200000	1.100000	3.520000000	2.909091
611018			2.500000	.600000	1.500000000	4.166667
611018			1.700000	.300000	.510000000	5.666667
611018			8.300000	.900000	7.470000000	9.222222
611018			1.700000	.600000	1.020000000	2.833333
611018			2.300000	.800000	1.840000000	2.875000
611018			6.500000	2.000000	13.000000000	3.250000
611018			5.700000	1.100000	6.270000000	5.181818
611018	10	AC	7.200000	1.400000	10.080000000	5.142857
611018	10	AC	4.600000	.800000	3.680000000	5.750000
611018	10	AC	5.100000	2.200000	11.220000000	2.318182
611018	10	AC	7.300000	.600000	4.380000000	* .1E+02
611018	10	AC	4.[illegible]	.600000	2.400000000	6.666667
611018	10	AC	2.200000	.400000	.880000000	5.500000
611018	10	AC	7.300000	3.100000	22.630000000	2.354839
611018	10	AC	2.100000	.400000	.840000000	5.250000
611018	10	AC	4.300000	.800000	3.440000000	5.375000
611018	10	AC	5.200000	2.800000	14.560000000	1.857143
611018	10	AC	3.900000	.800000	3.120000000	4.375000
611018	10	AC	3.100000	.600000	1.860000000	5.166667
611018	10	AC	2.[illegible]00000	.300000	.600000000	6.666667
611018	10	AC	5.400000	.900000	4.860000000	6.000000
611018	10	AC	2.900000	.400000	1.160000000	7.250000
611018	10	AC	2.800000	.900000	2.340000000	2.888889
611018	10	AC	3.700000	1.300000	4.810000000	2.846154
611018	10	AC	6.[illegible]00000	.800000	4.800000000	7.500000
611018	10	AC	4.100000	.800000	3.280000000	5.125000
611018	10	AC	3.700000	.900000	3.330000000	4.111111
611018	10	AC	2.[illegible]00000	1.000000	2.400000000	2.400000
611018	10	AC	1.900000	.800000	1.520000000	2.375000
611018	10	AC	9.[illegible]00000	2.000000	18.200000000	4.550000
611018	10	AC	7.400000	2.100000	15.540000000	3.523810
611018	10	AC	7.[illegible]00000	3.200000	22.400000000	2.187500
611018	10	AC	3.[illegible]00000	.[illegible]00000	2.[illegible]00000	4.[illegible]00000
611018	10	AC	4.[illegible]00000	.[illegible]00000	3.[illegible]00000	4.444444
611018	10	AC	4.[illegible]00000	1.700000	7.[illegible]00000	2.[illegible]

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4.200000	1.400000	5.880000000	3.500001
3.[illegible]	.600000	1.800000000	5.[illegible]
4.200000	.700000	2.940000000	5.[illegible]
2.[illegible]	.800000	2.320000000	3.525000
3.[illegible]	.900000	3.510000000	4.333333
1.[illegible]	.400000	.640000000	4.[illegible]
[illegible]	.500000	4.250000000	* .1E+02
9.700000	2.100000	20.370000000	4.619048
4.[illegible]	1.300000	6.370000000	3.769231
7.500000	1.200000	9.000000000	6.250000
* .1E+02	3.700000	37.740000000	2.756757
7.700000	1.400000	10.780000000	5.500000
4.500000	2.400000	10.800000000	1.875000
2.[illegible]	.800000	1.840000000	2.875000
3.100000	.700000	2.170000000	4.428571
2.600000	1.100000	2.860000000	2.363636
6.[illegible]	1.200000	8.160000000	5.466667
5.400000	2.200000	11.880000000	2.454545
3.100000	.800000	2.480000000	3.875000
* .1E+02	1.600000	17.920000000	7.500000
2.300000	.600000	1.380000000	3.833333
1.400000	.400000	.560000000	3.500000
2.700000	1.000000	2.700000000	2.700000
2.100000	.800000	1.680000000	2.625000
2.000000	2.100000	4.200000000	.952381
2.600000	.500000	1.300000000	5.200000
3.200000	.400000	1.280000000	8.000000
4.200000	2.000000	8.400000000	2.100000
* .1E+02	3.000000	33.600000000	3.733333
5.[illegible]	1.500000	7.500000000	3.333333
7.200000	2.200000	15.840000000	3.272727
7.300000	1.600000	11.680000000	4.562500
6.100000	2.600000	15.860000000	2.346154
3.800000	1.500000	5.700000000	2.533333
3.600000	2.400000	8.640000000	1.500000
2.300000	.700000	1.610000000	3.285714
8.300000	2.900000	24.070000000	2.862069
3.500000	2.000000	7.000000000	1.750000
2.100000	.800000	1.680000000	2.625000
6.300000	2.500000	15.750000000	2.520000
3.600000	1.800000	6.480000000	2.000000
6.500000	1.500000	9.750000000	4.333333
3.000000	.500000	1.500000000	6.000000
4.200000	2.200000	9.240000000	1.909091
2.200000	1.200000	2.640000000	1.833333
2.400000	1.100000	2.640000000	2.181818
1.700000	.800000	1.360000000	2.125000
* .1E+02	3.000000	31.200000000	3.466667
5.000000	4.700000	23.500000000	1.063830
4.200000	2.300000	9.660000000	1.826087
4.600000	1.200000	5.520000000	3.833333
3.700000	1.100000	4.070000000	3.363636
3.500000	2.600000	9.100000000	1.346154
9.000000	3.700000	33.300000000	2.432432
4.300000	1.300000	5.590000000	3.307692
1.800000	1.000000	1.800000000	1.800000
3.600000	1.300000	4.680000000	2.769231
2.000000	2.000000	4.000000000	1.000000
8.400000	1.500000	12.600000000	5.600000
1.[illegible]	.400000	.440000000	2.750000
8.[illegible]	1.900000	16.150000000	4.473684
5.[illegible]	2.800000	15.120000000	1.928571
2.[illegible]	1.100000	2.640000000	2.181818
2.[illegible]	1.300000	3.120000000	1.846154
3.[illegible]	.800000	2.[illegible]	4.375000
3.[illegible]	1.700000	5.950000000	2.058824

05573

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3.200000	1.400000	4.480000000	2.285714
2.400000	1.300000	3.120000000	1.846154
1.700000	1.500000	2.720000000	1.062500
2.300000	.800000	2.070000000	3.250000
4.200000	1.600000	6.720000000	2.625000
3.200000	1.400000	5.760000000	1.777778
2.300000	.400000	1.000000000	5.250000
3.400000	.400000	1.360000000	8.500000
2.700000	.700000	1.890000000	3.857143
1.300000	.500000	.650000000	2.500000
3.500000	1.000000	3.500000000	3.500000
5.100000	2.200000	11.000000000	2.272727
2.900000	.700000	2.630000000	4.142857
1.300000	.300000	.390000000	4.333333
1.800000	.900000	1.620000000	2.000000
4.500000	2.500000	11.250000000	1.800000
* .1E+02	3.700000	57.350000000	4.189189
4.300000	2.200000	9.460000000	1.954545
2.500000	.600000	1.500000000	4.166667
3.700000	2.500000	9.250000000	1.480000
4.500000	2.500000	11.250000000	1.800000
2.600000	2.000000	5.200000000	1.300000
2.100000	1.200000	2.520000000	1.750000
2.200000	3.000000	6.600000000	.733333
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5.700000	1.600000	9.120000000	3.562500
3.500000	1.900000	6.650000000	1.842105
2.800000	1.700000	4.760000000	1.647059
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2.400000	.800000	1.920000000	3.000000
1.500000	.700000	1.050000000	2.142857
6.700000	1.200000	8.040000000	5.583333
2.700000	1.500000	4.050000000	1.800000
1.400000	.600000	.840000000	2.333333
2.400000	1.100000	2.640000000	2.181818
1.700000	1.400000	2.380000000	1.214286
2.400000	1.200000	2.880000000	2.000000
3.700000	3.600000	13.320000000	1.027778
3.400000	2.400000	8.160000000	1.416667
7.100000	2.800000	19.880000000	2.535714
2.800000	1.100000	3.080000000	2.545455
3.400000	1.600000	5.440000000	2.125000
3.000000	1.400000	4.200000000	2.142857
2.900000	3.000000	8.700000000	.966667
2.200000	.500000	1.100000000	4.400000
3.400000	1.400000	4.760000000	2.428571
1.500000	1.800000	2.700000000	.833333
1.700000	1.800000	3.060000000	.944444
1.000000	.600000	.600000000	1.666667
5.100000	1.200000	6.840000000	4.250000
3.700000	2.200000	8.140000000	1.681818
2.300000	.800000	1.840000000	2.875000
6.800000	2.700000	17.820000000	2.444444
5.600000	1.800000	10.080000000	3.111111
3.700000	1.600000	5.920000000	2.456667

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611019AAA	1.100000	.500000	.550000000	2.200000
611019AAA	3.300000	.600000	2.340000000	3.500000
611019AAA	7.500000	2.100000	15.750000000	3.571429
611019AAA	3.500000	2.000000	7.000000000	1.750000
611019AAA	3.700000	1.600000	5.920000000	2.312500
611019AAA	6.500000	2.000000	13.000000000	3.250000
611019AAA	5.200000	2.100000	11.550000000	2.619048
611019AAA	4.500000	2.500000	11.250000000	1.800000
611019AAA	3.100000	1.200000	3.600000000	2.583333
611019AAA	2.500000	1.000000	2.500000000	2.500000
611019AAA	3.000000	1.100000	3.300000000	2.727273
611019AAA	2.600000	1.100000	2.860000000	2.363636
611019AAA	1.300000	1.200000	2.160000000	1.500000
611019AAA	1.800000	.400000	.560000000	3.500000
611019AAA	4.500000	1.800000	11.700000000	3.611111
611019AAA	3.100000	1.800000	5.580000000	1.722222
611019AAA	5.000000	1.700000	8.500000000	2.941176
611019AAA	* .1E+02	7.800000	83.460000000	1.371795
611019AAA	7.500000	4.400000	33.000000000	1.704545
611019AAA	7.600000	1.900000	13.680000000	4.222222
611019AAA	2.500000	1.300000	3.250000000	1.923077
611019AAA	3.100000	1.200000	3.720000000	2.583333
611019AAA	7.000000	2.300000	16.100000000	3.043478
611019AAA	2.300000	1.400000	3.220000000	1.642857
611019AAA	7.800000	5.300000	41.340000000	1.471698
611019AAA	4.000000	2.500000	10.000000000	1.600000
611019AAA	.900000	.700000	.630000000	1.285714
611019AAA	5.000000	2.800000	14.000000000	1.785714
611019AAA	8.400000	3.400000	28.560000000	2.470588
611019AAA	8.700000	5.900000	51.330000000	1.474576
611019AAA	2.000000	1.400000	2.800000000	1.428571
611019AAA	3.000000	1.400000	4.200000000	2.142857
611019AAA	2.500000	2.000000	5.000000000	1.250000
611019AAA	2.000000	1.500000	3.000000000	1.333333
611019AAA	2.000000	.800000	1.600000000	2.500000
611019AAA	1.300000	.900000	1.170000000	1.444444
611019AAA	1.500000	.800000	1.200000000	1.875000
611019AAA	1.600000	.700000	1.120000000	2.285714
611019AAA	2.300000	.900000	2.070000000	2.555556
611019AAA	2.500000	1.400000	3.500000000	1.785714
611019AAA	7.800000	3.600000	28.080000000	2.166667
611019AAA	4.400000	2.300000	10.120000000	1.913043
611019AAA	4.700000	1.700000	7.990000000	2.764706
611019AAA	2.800000	1.800000	5.040000000	1.555556
611019AAA	1.100000	1.000000	1.100000000	1.100000
611019AAA	2.500000	.900000	2.250000000	2.777778
611019AAA	2.600000	1.600000	4.160000000	1.625000
611019AAA	2.600000	2.500000	6.500000000	1.040000
611019AAA	2.300000	1.700000	3.910000000	1.352941
611019AAA	1.200000	.700000	.840000000	1.714286
611019AAA	2.500000	2.500000	6.250000000	1.000000
611019AAA	1.500000	1.300000	1.950000000	1.153846
611019AAA	2.500000	1.400000	3.500000000	1.785714
611019AAA	6.000000	2.200000	13.200000000	2.727273
611019AAA	2.000000	.900000	1.800000000	2.222222
611019AAA	1.700000	1.000000	1.700000000	1.700000
611019AAA	4.200000	2.200000	9.240000000	1.909091
611019AAA	2.400000	1.900000	4.560000000	1.263158
611019AAA	4.500000	2.400000	10.800000000	1.875000
611019AAA	1.400000	.800000	1.120000000	1.750000
611019AAA	2.000000	1.300000	2.600000000	1.538462
M6150 1	7.500000	2.600000	19.500000000	2.884615
M6150 1	3.000000	1.300000	3.900000000	2.307692
M6150 1	4.100000	2.300000	9.430000000	1.782609
M6150 1	9.000000	3.200000	30.720000000	3.000000
M6150 1	1.700000	.900000	1.530000000	1.888889

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M6150 1	1.400000	1.000000	1.400000000	1.400000
M6150 1	1.200000	.400000	.720000000	4.500000
M6150 1	7.200000	2.300000	16.100000000	3.043478
M6150 1	2.700000	.900000	2.430000000	3.000000
M6150 1	2.500000	2.100000	5.460000000	1.238095
M6150 1	7.500000	2.900000	22.910000000	2.724138
M6150 1	3.600000	1.600000	6.080000000	2.375000
M6150 1	1.700000	1.000000	1.700000000	1.700000
M6150 2	9.600000	2.800000	26.880000000	3.428571
M6150 2	2.400000	.800000	1.920000000	3.000000
M6150 2	5.800000	2.400000	12.720000000	2.208333
M6150 2	3.000000	1.000000	3.000000000	3.000000
M6150 2	2.700000	.800000	2.240000000	3.500000
M6150 2	3.800000	.600000	2.160000000	6.333333
M6150 2	3.700000	1.300000	4.810000000	2.846154
M6150 2	2.100000	.800000	1.680000000	2.500000
M6150 2	2.500000	1.100000	2.860000000	2.363636
M6150 2	1.500000	.600000	.960000000	2.666667
M6227A 2	6.700000	1.000000	6.700000000	6.700000
M6227A 2	4.800000	3.400000	16.320000000	1.411765
M6227A 2	9.000000	1.800000	16.200000000	5.000000
M6227A 2	4.500000	1.500000	6.900000000	3.000000
M6227A 2	2.400000	.800000	1.920000000	3.000000
M6227A 2	2.900000	2.200000	6.380000000	1.318182
M6227A 2	3.400000	1.500000	5.100000000	2.266667
M6227A 2	4.000000	1.600000	6.400000000	2.500000
M6227A 2	5.500000	2.000000	11.000000000	2.750000
M6227A 2	6.200000	2.100000	13.020000000	2.952381
M6227A 1	4.600000	1.400000	6.440000000	3.285714
M6227A 1	3.700000	.800000	2.960000000	4.625000
M6227A 1	4.300000	1.000000	4.300000000	4.300000
M6227A 1	2.300000	2.400000	5.520000000	.958333
M6227A 1	3.600000	.600000	2.160000000	6.000000
M6227A 1	4.100000	.400000	1.640000000	* .1E+02
M6227A 1	1.500000	.300000	.450000000	5.000000
M6227A 1	1.700000	.300000	.510000000	5.666667
M6227A 1	3.200000	.600000	1.920000000	5.333333
M6227A 1	3.900000	.500000	1.950000000	7.800000
M6227A 1	9.600000	1.800000	17.280000000	5.333333
M6227A 1	5.000000	.500000	2.500000000	* .1E+02
M6227A 1	6.500000	1.500000	9.750000000	4.333333
M6227A 1	1.900000	1.000000	1.900000000	1.900000
M6227A 1	4.000000	1.000000	4.000000000	4.000000
M6227A 1	2.300000	.400000	.920000000	5.750000
M6227A 1	1.800000	1.100000	1.980000000	1.636364
M6227A 1	2.600000	.700000	1.820000000	3.714286
M6227A 1	4.900000	1.300000	6.370000000	3.769231
M6227A 1	3.600000	.600000	2.160000000	6.000000
M6227A 1	1.500000	.800000	1.200000000	1.875000
M6225	6.700000	2.000000	13.400000000	3.350000
M6225	1.800000	.900000	1.620000000	2.000000
M6225	3.100000	1.100000	3.410000000	2.818182
M6225	4.000000	1.400000	5.600000000	2.857143
M6225	1.400000	.400000	.560000000	3.500000
M6225	3.300000	1.500000	4.950000000	2.200000
M6225	2.700000	1.700000	4.590000000	1.588235
M6225	3.400000	.500000	1.700000000	6.800000
M6225	4.000000	.800000	3.200000000	5.000000
M6225	6.200000	1.000000	6.200000000	6.200000
M6225	3.500000	.900000	3.150000000	3.888889
M6225	2.300000	.300000	.780000000	8.666667
M6225	3.500000	.800000	2.800000000	4.375000
M6225	4.600000	1.000000	4.600000000	4.600000
M6225	4.200000	1.500000	6.300000000	2.800000
M6225	4.100000	1.900000	7.790000000	2.157895
M6225	6.900000	1.500000	10.350000000	4.600000

M6222	3.[illegible]	1.000000	3.[illegible]	3.[illegible]
M6222	2.[illegible]	1.000000	2.500000000	2.[illegible]
M6222	2.[illegible]	.900000	1.800000000	2.222222
M6222	3.[illegible]	1.200000	3.600000000	2.500000
M6222	2.[illegible]	.800000	1.680000000	4.[illegible]
M6222	2.[illegible]	.900000	2.340000000	2.[illegible]
M6222	4.[illegible]	1.800000	7.360000000	2.[illegible]
M6222	3.[illegible]	2.[illegible]	7.[illegible]	1.[illegible]
M6222	4.[illegible]	1.000000	4.000000000	4.000000
M6222	4.[illegible]	1.[illegible]	5.[illegible]	2.[illegible]
M6222	3.[illegible]	.900000	2.880000000	3.555555
M6222	2.[illegible]	.500000	1.300000000	5.[illegible]
M6222	2.[illegible]	.600000	1.500000000	4.166667
M6222	1.[illegible]	.400000	.760000000	4.750000
M6222	5.[illegible]	2.000000	10.[illegible]	2.500000
M6222	5.[illegible]	1.300000	6.760000000	4.000000
M6222	3.[illegible]	.900000	2.790000000	3.444444
M6222	3.[illegible]	2.500000	8.750000000	1.460000
M6222	3.[illegible]	1.300000	4.680000000	2.769231
M6222	3.100000	1.300000	4.030000000	2.384615
M6222	4.500000	1.200000	5.400000000	3.750000
M6222	3.700000	.900000	3.330000000	4.111111
M6222	3.800000	1.400000	5.320000000	2.714286
M6222	5.300000	2.600000	13.780000000	2.038462
M6227	3.400000	.900000	3.060000000	3.777778
M6227	2.200000	1.100000	2.420000000	2.000000
M6227	1.800000	.500000	.800000000	3.200000
M6227	3.200000	1.400000	4.480000000	2.285714
M6227	3.300000	2.300000	7.590000000	1.434783
M6227	1.900000	.300000	.570000000	6.333333
M6227	2.500000	.400000	1.000000000	6.250000
M6227	3.000000	.700000	2.100000000	4.285714
M6227	3.400000	1.300000	4.420000000	2.615385
M6227	3.100000	1.200000	3.720000000	2.583333
M6227	3.800000	1.400000	5.320000000	2.714286
M6227	2.600000	1.100000	2.860000000	2.363636
M6227	3.800000	1.000000	3.800000000	3.800000
M6227	5.000000	1.800000	9.000000000	2.777778
M6227	2.400000	.700000	1.680000000	3.428571
M6227	3.900000	1.000000	3.900000000	3.900000
M6227	2.100000	.900000	1.890000000	2.333333
M6227	4.500000	1.500000	6.750000000	3.000000
6111134AA	3.800000	1.100000	4.180000000	3.454545
6111134AA	3.700000	1.500000	5.550000000	2.466667
6111134AA	3.500000	1.600000	5.600000000	2.187500
6111134AA	1.700000	.600000	1.020000000	2.833333
6111134AA	7.000000	1.700000	11.900000000	4.117647
6111134AA	5.900000	1.400000	8.260000000	4.214286
6111134AA	3.100000	1.800000	5.580000000	1.722222
6111134AA	4.100000	1.300000	5.330000000	3.153846
6111134AA	7.600000	1.800000	13.680000000	4.222222
6111134AA	8.700000	1.900000	16.530000000	4.578947
6111134AA	6.900000	2.600000	17.940000000	2.653846
6111134AA	5.900000	1.700000	10.030000000	3.470588
6111134AA	7.000000	1.800000	12.600000000	3.888889
6111134AA	4.100000	1.300000	5.330000000	3.153846
6111134AA	* .1E+02	2.200000	27.720000000	5.727273
6111134AA	4.500000	1.600000	7.200000000	2.812500
6111134AA	5.500000	1.400000	7.700000000	3.928571
6111134AA	4.300000	1.000000	4.300000000	4.300000
6111134AA	3.700000	.600000	2.220000000	6.166667
6111134AA	1.400000	.800000	1.120000000	1.750000
6111134AA	2.000000	.900000	1.800000000	2.222222
6111134AA	7.[illegible]	3.[illegible]	23.[illegible]	2.312500
6111134AA	3.[illegible]	1.[illegible]	5.[illegible]	2.125000
6111134AA	3.[illegible]	1.[illegible]	5.[illegible]	1.833333

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61111346A	2.500000	1.000000	2.500000000	2.500000
61111346A	7.900000	2.500000	19.750000000	3.160000
61111346A	* .1E+02	2.500000	25.000000000	4.240000
61111346A	* .1E+02	3.400000	34.000000000	2.976585
61111346A	5.300000	2.200000	11.660000000	2.409091
61111346A	3.900000	.800000	2.880000000	4.500000
61111346A	2.700000	1.000000	2.700000000	2.700000
61111346A	4.500000	2.300000	10.350000000	1.956522
61111346A	4.400000	.900000	3.960000000	4.888889
61111346A	3.200000	1.000000	3.200000000	3.200000
61111346A	3.500000	1.600000	5.600000000	2.197500
61111346A	3.800000	.800000	3.040000000	4.750000
61111346A	3.700000	.700000	2.590000000	5.285714
61111346A	1.800000	.900000	1.620000000	2.000000
61111346A	1.900000	.500000	.950000000	3.800000
61111346A	4.600000	1.500000	6.900000000	3.066667
61111346A	3.700000	1.400000	5.660000000	2.055556
M6221	4.500000	1.400000	6.300000000	3.214286
M6221	5.300000	1.600000	8.480000000	3.312500
M6221	4.700000	2.100000	9.870000000	2.238095
M6221	4.500000	1.200000	5.400000000	3.750000
M6221	2.600000	.900000	2.340000000	2.888889
M6221	2.400000	.800000	1.920000000	3.000000

TOTAL NUMBER OF SAMPLES 417

Table 2. Modal proportions of olivine, plagioclase, clinopyroxene, orthopyroxene, opaque minerals, biotite and symplectite in troctolitic-gabbroic series rocks from the Kawishiwi area.

Data were obtained by Keith Rosvold by point-counting of minerals at the intersections of a 5mm grid on the photomicrographs in Part 2. Positive identification of fine-grained minerals was made on the actual thin sections with the polarizing microscope.

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MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

MINERAL	1 M6227A(1 COUNT	PERCENT	2 M6227A(2 COUNT	PERCENT	3 M6227A COUNT	PERCENT	4 M6227 COUNT	PERCENT	5 M6227 COUNT	PERCENT
OLIVINE	247	28.33	184	29.68	369	30.00	40	7.33	102	8.50
PLAGIOCLASE	582	66.74	400	64.52	842	68.46	352	64.47	761	63.42
CLINOPYROXENE	20	2.29	2	.32	3	.24	57	10.44	282	23.50
ORTHOPYROXENE	0	0	0	0	0	0	7	1.28	3	.25
OPAQUES	9	1.03	21	3.39	3	.24	48	8.79	32	2.67
BIOTITE	14	1.61	10	1.61	13	1.06	16	2.93	18	1.50
SYMPLECTITE	0	0	3	.48	0	0	26	4.76	2	.17
TOTAL	872	100.00	620	100.00	1230	100.00	546	100.00	1200	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

MINERAL	6 M6228 COUNT	PERCENT	7 6211332A COUNT	PERCENT	8 611132A COUNT	PERCENT	9 611133A COUNT	PERCENT	10 M6225 COUNT	PERCENT
OLIVINE	77	6.26	111	8.73	199	15.17	163	12.82	147	23.44
PLAGIOCLASE	1057	85.93	1054	82.93	1000	76.22	1049	82.53	421	67.15
CLINOPYROXENE	3	.24	25	1.97	61	4.65	13	1.02	0	0
ORTHOPYROXENE	0	0	18	1.42	2	.15	18	1.42	0	0
OPAQUES	78	6.34	31	2.44	39	2.97	14	1.10	50	7.97
BIOTITE	15	1.22	27	2.12	9	.69	14	1.10	9	1.44
SYMPLECTITE	0	0	5	.39	2	.15	0	0	0	0
TOTAL	1230	100.00	1271	100.00	1312	100.00	1271	100.00	627	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

MINERAL	11 611134A COUNT	PERCENT	12 611135B COUNT	PERCENT	13 611136A COUNT	PERCENT	14 611137A COUNT	PERCENT	15 M4222 COUNT	PERCENT
OLIVINE	92	7.48	126	9.38	81	6.43	138	10.95	69	5.34
PLAGIOCLASE	1078	87.64	1130	84.08	1050	83.33	1012	80.32	1190	92.18
CLINOPYROXENE	21	1.71	41	3.05	42	3.33	21	1.67	0	0
ORTHOPYROXENE	9	.73	14	1.04	37	2.94	22	1.75	15	1.16
OPAQUES	15	1.22	16	1.19	39	3.10	53	4.21	9	.70
BIOTITE	15	1.22	11	.82	11	.87	9	.71	8	.62
SYMPLECTITE	0	0	6	.45	0	0	5	.40	0	0
TOTAL	1230	100.00	1344	100.00	1260	100.00	1260	100.00	1291	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

MINERAL	16 61111317 COUNT	PERCENT	17 61113T3 COUNT	PERCENT	18 611121A COUNT	PERCENT	19 6111111A COUNT	PERCENT	20 M6221 COUNT	PERCENT
OLIVINE	123	9.29	101	7.76	68	5.53	117	9.01	980	88.85
PLAGIOCLASE	1083	81.80	1114	85.56	1136	92.36	1104	85.05	114	10.34
CLINOPYROXENE	43	3.25	22	1.69	6	.49	26	2.00	0	0
ORTHOPYROXENE	11	.83	20	1.54	12	.98	18	1.39	0	0
OPAQUES	40	3.02	38	2.92	3	.24	23	1.77	9	.82
BIOTITE	10	.76	5	.38	5	.41	9	.69	0	0
SYMPLECTITE	14	1.06	2	.15	0	0	1	.08	0	0
TOTAL	1324	100.00	1302	100.00	1230	100.00	1298	100.00	1103	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

MINERAL	21 6111112B COUNT	PERCENT	22 61111T3B COUNT	PERCENT	23 6111114A COUNT	PERCENT	24 6111115A COUNT	PERCENT	25 6T11116C COUNT	PERCENT
OLIVINE	210	16.72	74	5.68	145	11.14	213	15.85	254	19.98
PLAGIOCLASE	1004	79.94	1147	88.10	1113	85.48	1105	82.22	982	77.26
CLINOPYROXENE	2	.16	49	3.76	2	.15	10	.74	4	.31
ORTHOPYROXENE	6	.48	14	1.08	8	.61	5	.37	10	.79
OPAQUES	14	1.11	13	1.00	25	1.92	9	.67	14	1.10
BIOTITE	19	1.51	5	.38	7	.54	2	.15	5	.39
SYMPLECTITE	1	.08	0	0	2	.15	0	0	2	.16
TOTAL	1256	100.00	1302	100.00	1302	100.00	1344	100.00	1271	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

	26 6111117A		27 6111115A		28 6111134A		29 6111134B		30 6111138A	
MINERAL	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
OLIVINE	118	8.78	153	11.75	47	4.46	112	11.43	177	14.39
PLAGIOCLASE	1179	87.72	1119	85.94	949	90.04	798	81.43	943	76.67
CLINOPYROXENE	17	1.26	1	.08	28	2.66	47	4.80	87	7.07
ORTHOPYROXENE	16	1.19	3	.23	4	.38	11	1.12	4	.33
OPAQUES	8	.60	15	1.15	26	2.47	7	.71	16	1.30
BIOTITE	6	.45	3	.23	0	0	0	0	2	.16
SYMPLECTITE	0	0	8	.61	0	0	5	.51	1	.08
TOTAL	1344	100.00	1302	100.00	1054	100.00	980	100.00	1230	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

	31 M6150(1)		32 M6150(2)		33 61101819		34 61101813		35 6110194A	
MINERAL	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
OLIVINE	116	17.08	122	19.97	197	16.02	72	5.66	69	8.58
PLAGIOCLASE	561	82.62	458	74.96	1000	81.30	1180	92.84	729	90.67
CLINOPYROXENE	0	0	0	0	0	0	2	.16	2	.25
ORTHOPYROXENE	0	0	0	0	1	.08	2	.16	0	0
OPAQUES	2	.29	23	3.76	12	.98	13	1.02	4	.50
BIOTITE	0	0	0	0	5	.41	2	.16	0	0
SYMPLECTITE	0	0	8	1.31	15	1.22	0	0	0	0
TOTAL	679	100.00	611	100.00	1230	100.00	1271	100.00	804	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

	36	6110195A	37	6110197A	38	6110199A	39	6110198A	40	M6233
MINERAL	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
OLIVINE	149	12.95	34	2.55	0	0	24	1.89	15	1.22
PLAGIOCLASE	989	85.93	1139	85.45	1338	97.24	1237	97.32	1082	87.97
CLINOPYROXENE	9	.78	159	11.93	28	2.03	4	.31	61	4.96
ORTHOPYROXENE	0	0	0	0	0	0	0	0	0	0
OPAQUES	4	.35	1	.08	10	.73	5	.39	65	5.28
BIOTITE	0	0	0	0	0	0	1	.08	7	.57
SYMPLECTITE	0	0	0	0	0	0	0	0	0	0
TOTAL	1151	100.00	1333	100.00	1376	100.00	1271	100.00	1230	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

	41	6110196A	42	6110195A	43	6110186A	44	6110187A	45	6110188A
MINERAL	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
OLIVINE	74	12.33	119	11.76	17	3.06	89	8.16	143	21.41
PLAGIOCLASE	524	87.33	838	82.81	519	93.51	965	88.45	516	77.25
CLINOPYROXENE	0	0	34	3.36	0	0	5	.46	0	0
ORTHOPYROXENE	0	0	0	0	0	0	0	0	0	0
OPAQUES	2	.33	21	2.08	19	3.42	32	2.93	9	1.35
BIOTITE	0	0	0	0	0	0	0	0	0	0
SYMPLECTITE	0	0	0	0	0	0	0	0	0	0
TOTAL	600	100.00	1012	100.00	555	100.00	1091	100.00	668	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

	46	61101898	47	61101898	48	61101810	49	61101810	50	61101810
MINERAL	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
OLIVINE	157	10.04	161	13.03	349	28.65	396	32.67	388	30.60
PLAGIOCLASE	1157	73.98	926	74.92	837	68.72	777	64.11	830	65.46
CLINOPYROXENE	221	14.13	131	10.60	1	.08	0	0	5	.39
ORTHOPYROXENE	0	0	0	0	0	0	0	0	0	0
OPAQUES	29	1.85	18	1.46	28	2.30	35	2.89	29	2.29
BIOTITE	0	0	0	0	2	.16	3	.25	12	.95
SYMPLECTITE	0	0	0	0	1	.08	1	.08	4	.32
TOTAL	1564	100.00	1236	100.00	1218	100.00	1212	100.00	1268	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

	51	62113533	52	62113534	53	62113534	54	62113534	55	62113516
MINERAL	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
OLIVINE	204	15.55	302	23.76	479	38.63	176	13.41	323	28.84
PLAGIOCLASE	1032	78.66	929	73.09	704	56.77	1065	81.17	705	62.95
CLINOPYROXENE	16	1.22	21	1.65	11	.89	6	.46	42	3.75
ORTHOPYROXENE	36	2.74	11	.87	12	.97	19	1.45	3	.27
OPAQUES	10	.76	2	.16	26	2.10	29	2.21	34	3.04
BIOTITE	14	1.07	6	.47	8	.65	7	.53	7	.63
SYMPLECTITE	0	0	0	0	0	0	10	.76	6	.54
TOTAL	1312	100.00	1271	100.00	1240	100.00	1312	100.00	1120	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

	56	62112590	57	62112555	58	62112512	59	62112559	60	62112560
MINERAL	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
OLIVINE	162	13.40	233	18.20	196	15.42	242	18.91	156	12.58
PLAGIOCLASE	1033	85.44	940	73.44	911	71.68	849	66.33	901	72.66
CLINOPYROXENE	0	0	49	3.83	150	11.80	68	5.31	147	11.85
ORTHOPYROXENE	0	0	15	1.17	4	.31	18	1.41	12	.97
OPAQUES	8	.66	29	2.27	5	.39	63	4.92	17	1.37
BIOTITE	6	.50	10	.78	4	.31	26	2.03	5	.40
SYMPLECTITE	0	0	4	.31	1	.08	14	1.09	2	.16
TOTAL	1209	100.00	1280	100.00	1271	100.00	1280	100.00	1240	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

	61	62112410	62	62112412	63	62112417	64	62112413	65	62112421
MINERAL	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
OLIVINE	543	42.72	458	36.41	135	11.25	171	14.25	262	22.04
PLAGIOCLASE	654	51.46	648	51.51	968	80.67	922	76.83	842	70.82
CLINOPYROXENE	50	3.93	142	11.29	52	4.33	59	4.92	17	1.43
ORTHOPYROXENE	0	0	0	0	7	.58	4	.33	2	.17
OPAQUES	18	1.42	6	.48	30	2.50	15	1.25	49	4.12
BIOTITE	6	.47	4	.32	5	.42	16	1.33	8	.67
SYMPLECTITE	0	0	0	-0	3	.25	13	1.08	9	.76
TOTAL	1271	100.00	1258	100.00	1200	100.00	1200	100.00	1189	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

	66	62101974	67	62101974	68	62101979	69	M6223	70	62113519
MINERAL	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
OLIVINE	249	23.21	218	16.74	90	6.91	256	20.81	76	6.18
PLAGIOCLASE	743	69.25	966	74.19	1005	77.19	869	70.65	1089	88.54
CLINOPYROXENE	57	5.31	91	6.99	176	13.52	79	6.42	35	2.85
ORTHOPYROXENE	1	.09	4	.31	2	.15	0	0	3	.24
OPAQUES	8	.75	16	1.23	8	.61	24	1.95	16	1.30
BIOTITE	10	.93	7	.54	19	1.46	1	.08	11	.89
SYMPLECTITE	5	.47	0	0	2	.15	1	.08	0	0
TOTAL	1073	100.00	1302	100.00	1302	100.00	1230	100.00	1230	100.00

MINERAL PROPORTIONS HWY NO. 1 TRAVERSE

	71	62113531	72	62113528	73	62112416	0		0	
MINERAL	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
OLIVINE	125	10.51	44	3.58	234	18.87	0	0	0	0
PLAGIOCLASE	943	79.31	1098	89.27	936	75.48	0	0	0	0
CLINOPYROXENE	24	2.02	34	2.76	6	.48	0	0	0	0
ORTHOPYROXENE	4	.34	5	.41	2	.16	0	0	0	0
OPAQUES	62	5.21	45	3.66	56	4.52	0	0	0	0
BIOTITE	15	1.26	4	.33	5	.40	0	0	0	0
SYMPLECTITE	16	1.35	0	0	1	.08	0	0	0	0
TOTAL	1189	100.00	1230	100.00	1240	100.00	0	0	0	0

561917

HIGHWAY 1 TRAVERSE MODAL PERCENT OLIVINE

DISTANCE	MODAL PERCENT	ID
.24	26.33	M6227A
.24	29.68	M6227A
.24	30.00	M6227A
.28	7.33	M6227
.28	3.50	M6227
.55	6.26	M6228
.74	8.73	621133
1.70	15.17	611132
1.36	12.82	611133
1.93	23.44	M6225
1.95	7.48	611134
2.29	9.38	611135
2.43	6.43	611136
2.51	15.95	611137
2.99	5.34	M6222
3.40	9.29	611113
3.47	7.76	611131
3.61	5.53	611121
3.71	9.01	611111
4.01	16.72	611111
4.15	5.08	611111
4.42	11.14	611111
4.95	15.95	611111
5.17	19.98	611111
5.43	8.73	611111
5.72	11.75	611112
7.08	4.46	611113
7.28	11.43	611113
7.42	14.39	611113
7.62	17.05	M6150(
7.65	19.07	M6150(
7.99	16.02	611018
8.71	5.65	611018
9.01	5.58	611019
9.15	12.95	611019
9.51	2.55	611019
9.81	0	611019
9.88	1.89	611019

90 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(-.176 .301)(-.075 .447)(.031 .526)(.145 .605)(.265 .679)(.393 .749)(.529 .816)(.675 .880)(.832 .941)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 38

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X

A0 = 15.41 +- 1.99

A1 = -.82 +- .37

STANDARD ERROR = 7.00

CORRELATION COEFFICIENT R = -.29741

HIGHWAY 1 TRAVERSE MODAL PERCENT PLAGIOCLASE

DISTANCE	MODAL PERCENT	ID
.24	66.74	M6227A
.24	64.52	M6227A
.24	63.40	M6227A
.26	64.47	M6227
.26	63.42	M6227
.65	85.93	M6228
.74	82.93	621133
1.70	76.22	611132
1.86	82.53	611133
1.93	67.15	M6225
1.95	87.64	611134
2.29	84.[illegible]8	611135
2.43	83.33	611136
2.51	8[illegible].32	611137
2.59	9[illegible].18	M6222
3.43	81.8[illegible]	611113
3.47	8[illegible].56	611131
3.61	92.36	611121
3.71	85.05	611111
4.01	79.94	611111
4.15	8[illegible].1[illegible]	611111
4.42	8[illegible].4[illegible]	611111
4.93	8[illegible].22	611111
5.17	77.26	611111
5.45	87.72	611111
5.72	85.94	611112
7.26	9[illegible].[illegible]4	611113
7.26	8[illegible].43	611113
7.42	76.07	611113
7.42	82.62	M6150(
7.46	74.96	M6150(
7.99	81.3[illegible]	611016
8.71	9[illegible].84	611018
9.01	9[illegible].67	611019
9.1[illegible]	85.93	611019
9.51	85.45	611019
9.81	97.24	611019
9.86	97.32	611019

9 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(-.176 .361)(-.075 .447)(.031 .528)(.145 .605)(.265 .679)(.393 .749)(.529 .816)(.675 .880)(.832 .941)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 38

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X

A0 = 74.61 +- 2.04

A1 = 1.67 +- .38

STANDARD ERROR = 7.19

CORRELATION COEFFICIENT R = .59435

DIAGRAM 1 TRAVERSE MODAL PERCENT CLINOPYROXENE

DISTANCE	MODAL PERCENT	ID
.24	2.29	M6227A
.24	.32	M6227A
.24	.24	M6227A
.26	11.44	M6227
.29	22.55	M6227
.68	.24	M6228
.74	1.97	621133
1.76	4.65	611132
1.80	1.32	611133
1.93	[illegible]	M6225
1.95	1.71	611134
2.29	3.55	611135
2.43	3.33	611136
2.51	1.57	611137
2.59	[illegible]	M6222
3.49	3.45	611113
3.67	1.69	611131
3.[illegible]	.49	611121
3.71	2.[illegible]	611111
4.[illegible]	.16	611111
4.15	3.76	611111
4.46	.15	611111
4.93	.74	611111
5.17	.31	611111
5.45	1.38	611111
5.76	.[illegible]	611112
7.[illegible]	7.[illegible]	611113
7.21	[illegible]	611113
7.42	7.[illegible]	611113
7.42	[illegible]	M6156(
7.46	[illegible]	M6156(
7.79	[illegible]	611 18
8.71	.16	611118
9.11	.25	611119
9.1[illegible]	.78	611119
9.[illegible]	11.43	611119
9.11	2.[illegible]3	611119
9.[illegible]	.51	611119

95 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(-.170 .361)(-.075 .447)(.031 .528)(.145 .605)(.265 .679)(.393 .749)(.529 .816)(.675 .880)(.832 .941)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 38

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X

A0 =	3.62 +-	1.26
A1 =	-.23 +-	.23
STANDARD ERROR =		4.43

CORRELATION COEFFICIENT R = -.14350

TOMAY 1 TRAVERSE MODAL PERCENT OPAQUES

DISTANCE	MODAL PERCENT	ID
.24	1.03	M6227A
.24	3.37	M6227A
.24	.24	M6227A
.26	8.79	M6227
.26	2.67	M6227
.65	6.34	M6228
.74	2.44	621133
1.70	2.97	611132
1.86	1.15	611133
1.93	7.97	M6225
1.95	1.22	611134
2.29	1.19	611135
2.43	5.16	611136
2.51	4.21	611137
2.99	.76	M6222
3.40	3.42	611113
3.47	2.32	611131
3.61	.24	611121
3.71	1.77	611111
4.01	1.11	611111
4.15	1.23	611111
4.42	1.42	611111
4.63	.57	611111
5.17	1.19	611111
5.65	.33	611111
5.72	1.15	611112
7.20	3.47	611113
7.21	.71	611113
7.42	1.31	611113
7.44	.24	M6150(
7.46	3.76	M6150(
7.55	.98	611018
8.71	1.12	611018
9.01	.52	611019
9.11	.35	611019
9.33	.38	611019
9.51	.73	611019
9.66	.39	611019

95 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(-.170 .361)(-.075 .447)(.031 .528)(.145 .605)(.265 .679)(.393 .749)(.529 .816)(.675 .880)(.832 .941)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 38

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X

A0 = 3.39 +- .51

A1 = -.32 +- .09

STANDARD ERROR = 1.60

CORRELATION COEFFICIENT R = -.46687

WAY 1 TRAVERSE MODAL PERCENT BIOTITE

DISTANCE	MODAL PERCENT	ID
.24	1.61	M6227A
.24	1.61	M6227A
.24	1.06	M6227A
.2[illegible]	2.93	M6227
.2[illegible]	1.5[illegible]	M6227
.[illegible]	1.22	M6228
.74	2.12	621133
1.7[illegible]	.69	611132
1.66	1.1[illegible]	611133
1.93	1.44	M6225
1.[illegible]	1.22	611134
2.29	.82	611135
2.[illegible]	.67	611136
2.[illegible]	.71	611137
2.[illegible]	.62	M6222
3.[illegible]	.76	611113
3.47	.36	611131
3.61	.41	611121
3.71	.69	611111
4.[illegible]	1.51	611111
4.15	.38	611111
4.[illegible]	.54	611111
4.[illegible]	.15	611111
5.17	.39	611111
5.[illegible]	.45	611111
5.72	.23	611112
7.2[illegible]	0	611113
7.[illegible]	0	611113
7.[illegible]	.16	611113
7.[illegible]	0	M6150(
7.[illegible]	0	M6150(
7.[illegible]	.41	611118
8.71	.16	611118
9.[illegible]	0	611019
9.1[illegible]	0	611019
9.[illegible]	0	611019
9.[illegible]	0	611019
9.[illegible]	.38	611019

9. PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR P = .1 THROUGH .9 (.05 .14)

(-.176 .561)(-.075 .447)(.031 .528)(.145 .605)(.265 .679)(.393 .749)(.529 .816)(.675 .880)(.832 .941)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 38

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X
A0 = 1.48 +- .11
A1 = -.18 +- .02
STANDARD ERROR = .40

CORRELATION COEFFICIENT R = -.75134

HIGHWAY 1 TRAVERSE MODAL PERCENT SYMPLECTITE

DISTANCE	MODAL PERCENT	ID
.24	0	M6227A
.44	.48	M6227A
.24	0	M6227A
.34	4.76	M6227
.28	.17	M6227
.05	0	M6228
.74	.39	621133
1.78	.15	611132
1.59	0	611133
1.43	0	M6225
1.45	0	611134
2.29	.45	611135
2.43	0	611136
2.51	.47	611137
2.53	0	M6222
3.06	1.06	611113
3.27	.13	611131
3.31	0	611121
3.71	.28	611121
4.11	.68	611111
4.15	0	611111
4.42	.19	611111
4.55	0	611111
5.17	.16	611111
5.45	0	611111
5.72	.61	611112
7.16	0	611112
7.38	.51	611113
7.62	.28	611113
7.82	0	M6150(
7.86	1.31	M6150(
7.94	1.22	611118
8.71	0	611118
9.01	0	611119
9.15	0	611119
9.31	0	611119
9.41	0	611119
9.88	0	611119

95 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(-.176 .361)(-.75 .447)(.31 .528)(.145 .605)(.265 .679)(.393 .749)(.529 .816)(.675 .880)(.832 .941)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSORPY SUBROUTINE

NUMBER OF DATA POINTS = 38

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X

A0 = .53 +- .23

A1 = -.05 +- .04

STANDARD ERROR = .81

CORRELATION COEFFICIENT R = -.17597

Table 3. Electron microprobe analyses of olivine in troctolitic-gabbroic series rocks from the Kawishiwi area.

The electron microprobe analyses were made by James Dunlavey on polished thin sections (see photomicrographs Part 2). Analyses were made on the electron microprobe analyzer (MAC, model 400) in the Department of Geology and Geophysics at the University of Minnesota. A 20 K.V., 0.015 microampere, 5 micrometer diameter electron beam was used to obtain K alpha X-ray intensity data on a natural wet chemically analyzed standard (YS-15) and the samples. Three elements were analyzed simultaneously with a 40 second counting interval and 20 second counts on either side of the K alpha peaks. Data were corrected for background and reduced to weight percent with an on-line PDP-11 Computer.

3-5 analyses were made on each sample and average values are given in Table 3. For olivine the cations should add to 3 (e.g.-$Mg_2S.O_4$) and minor elements other than those analyzed--Ca, Mn, Ni should be less than 0.5 percent so oxide sums are indicative of the reliability of the analyses. The limits of detection for the electron microprobe are in the 100-1000 ppm range depending on the element and matrix. Therefore the Ni data have very large errors and are only included to indicate the random error for these routine analyses. Ni content parallels Mg in olivines and in the range of compositions listed in Table 3, Ni should be in the range of 0.01-0.1 weight percent (Appendix 1, p. 10; Appendix 4, p. 18). A general study of the errors in the electron microprobe will be made in the future analyses of the Hoyt Lakes traverse samples.

TABLE 3. OLIVINE COMPOSITIONS MINNESOTA HIGHWAY 1 TRAVERSE

TABLE #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SAMPLE #	6211332	6233 2A	6233 2A	6233 2A	6233 2A	611132A	611132A	611132A	611132A	611132A	611132A	611133A	611133A	611133A	611133A
SiO2	39.00	37.40	35.10	38.80	38.80	33.90	35.60	34.20	34.50	33.20	33.20	38.80	35.10	35.70	36.50
AL2O3	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
FEO	34.00	38.70	38.30	36.60	40.20	36.20	35.90	37.20	37.30	37.40	37.50	41.50	40.40	40.90	41.00
MGO	28.61	22.50	24.80	25.70	21.20	28.30	27.80	29.10	29.30	28.60	28.70	25.60	25.40	25.00	25.70
CAO	.03	-0	-0	-0	.03	.05	.08	.03	.06	.03	.02	.03	.05	.03	.04
NA2O	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
K2O	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
TIO2	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
P2O5	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
MNO	.25	-0	-0	-0	-0	.74	.25	.21	.34	.37	.25	.04	.12	.13	.11
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
NIO	-0	-0	.30	.08	.10	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
TOTAL	97.69	98.60	98.59	101.18	100.33	99.19	99.63	100.74	101.50	99.60	99.67	103.34	101.07	102.76	103.35
CATIONIC PROPORTIONS BASED ON 4 OXYGENS															
SI	1.110	1.063	1.006	1.059	1.086	.962	.996	.956	.957	.944	.943	.989	.989	.988	.995
AL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FE	.793	.920	.918	.835	.941	.859	.840	.870	.865	.889	.891	.965	.952	.947	.953
MG	.981	.952	1.060	1.045	.884	1.197	1.160	1.213	1.211	1.212	1.216	1.054	1.067	1.072	1.041
CA	.001	0	0	0	.001	.002	.002	.001	.002	.001	.001	.001	.002	.001	.001
AL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MN	.006	0	0	0	0	.018	.006	.005	.008	.009	.006	.002	.003	.003	.003
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NI	0	0	.009	.002	.002	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2.890	2.937	2.994	2.941	2.914	3.038	3.004	3.044	3.043	3.056	3.057	3.011	3.011	3.014	3.014
MG/MG+FE	55.30	50.89	53.58	55.59	48.45	58.22	57.99	58.23	58.34	57.68	57.70	52.19	52.84	53.12	52.41

TABLE 3: OLIVINE COMPOSITIONS MINNESOTA HIGHWAY 1 TRAVERSE

TABLE #	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
SAMPLE #	611133A	611133A	611133A	611133A	611133A	613 3A1	613 3A1	613 3A1	613 3A1	613 3A1	611134A	611134A	611134A	611134A	611134A
SiO2	34.70	35.20	36.10	37.00	38.50	38.30	37.60	37.10	36.80	36.80	36.10	35.50	35.80	35.60	36.00
Al2O3	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
FeO	42.20	41.20	37.40	36.70	36.10	36.20	36.20	36.70	36.60	37.20	37.60	38.40	38.70	39.20	37.20
MgO	25.10	25.20	26.50	26.50	25.90	26.50	28.30	27.90	27.70	27.10	22.90	24.70	22.90	23.00	23.00
CaO	.03	.04	.04	.05	.15	.05	.01	.30	.05	0	.07	.02	.01	.02	.03
MnO	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
K2O	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
TiO2	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
P2O5	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
NiO	.11	.13	.57	.81	.51	.47	.29	.44	.41	.34	.48	.33	.16	.53	.45
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
NiO	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
TOTAL	102.14	101.77	100.61	101.06	101.16	101.52	102.40	102.44	101.56	101.44	97.15	98.95	97.57	98.35	96.67

CATIONS PROPORTIONS BASED ON 4 OXYGENS

SI	.976	.988	1.006	1.021	1.052	1.043	1.017	1.008	1.009	1.012	1.044	1.013	1.036	1.020	1.045
AL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FE	.993	.967	.872	.847	.825	.825	.819	.834	.839	.855	.914	.915	.936	.945	.903
MG	1.052	1.054	1.101	1.090	1.055	1.076	1.141	1.130	1.132	1.111	.988	1.050	.988	.988	.995
CA	.001	.001	.001	.001	.004	.001	.000	.009	.001	0	.002	.001	.000	.001	.001
NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MN	.003	.003	.013	.019	.012	.011	.007	.010	.010	.008	.012	.008	.004	.013	.011
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3.024	3.012	2.994	2.979	2.948	2.957	2.983	2.992	2.991	2.988	2.956	2.987	2.964	2.974	2.955
MG/MG+FE	51.46	52.16	55.81	56.28	56.12	56.61	58.22	57.54	57.43	56.49	52.05	53.41	51.33	51.12	52.43

TABLE 3. OLIVINE COMPOSITIONS MINNESOTA HIGHWAY 1 TRAVERSE

TABLE #	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
SAMPLE #	611136A	611136A	611136A	611136A	611136A	611136A	611136A	611136A	611136A	611136A	611137A	611137A	611137A	611137A	611137A
SiO2	34.70	32.40	32.90	32.20	35.20	34.80	35.10	35.10	33.90	35.10	35.00	34.70	35.70	35.40	37.10
Al2O3	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
FeO	39.30	41.40	40.60	41.10	40.10	39.60	39.80	39.70	41.10	40.30	41.90	41.50	41.30	42.10	42.50
MgO	23.50	24.70	23.40	23.80	23.70	23.00	24.00	23.70	23.80	23.50	21.10	20.70	20.30	20.50	22.10
CaO	.04	.06	.03	.04	.03	.03	.04	.03	.02	.03	.02	.09	.04	.05	-0
Na2O	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
K2O	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
TiO2	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
P2O5	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
MnO	.48	.46	.48	.50	.55	.54	.51	.50	.49	.51	.77	.76	.73	.54	.41
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
NiO	.21	.13	-0	.09	.05	.04	.03	.09	.10	.29	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
TOTAL	98.43	99.15	97.41	97.73	99.63	98.01	99.53	99.11	99.41	99.73	98.79	97.75	98.07	98.59	102.11

CATION PROPORTIONS BASED ON 4 OXYGENS

SI	1.008	.947	.974	.956	1.007	1.012	1.004	1.008	.981	1.005	1.021	1.023	1.043	1.032	1.031
AL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FE	.954	1.012	1.006	1.020	.960	.963	.952	.954	.995	.966	1.022	1.023	1.009	1.026	.994
MG	1.017	1.077	1.033	1.053	1.011	.997	1.024	1.015	1.027	1.004	.917	.910	.884	.885	.921
CA	.001	.002	.001	.001	.001	.001	.001	.001	.001	.001	.003	.001	.004	0	0
NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MN	.012	.011	.012	.013	.013	.013	.012	.012	.012	.012	.019	.019	.018	.013	.010
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NI	.006	.003	0	.002	.001	.001	.002	.002	.002	.007	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2.992	3.053	3.026	3.044	2.993	2.988	2.996	2.992	3.019	2.995	2.979	2.977	2.957	2.960	2.962
MG/MG+FE	51.59	51.54	50.67	50.79	51.30	50.87	51.80	51.56	50.79	50.97	47.30	47.06	46.70	46.59	48.10

TABLE 3: OLIVINE COMPOSITIONS MINNESOTA HIGHWAY 1 TRAVERSE

TABLE #	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
SAMPLE #	6111137A	6111137A	6111313	613 13A	613 13A	613 13A	613 13A	613 13A	61 11 1	6111 1A	6111 1A	6111 1A	6111 1A	6111 1A	6111134
SIO2	36.90	36.80	33.90	35.50	34.30	34.90	34.60	34.10	37.40	34.80	34.30	36.50	34.50	35.20	37.30
AL2O3	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
FEO	42.60	43.00	38.00	39.20	37.80	41.10	41.10	40.70	37.10	37.60	38.10	37.50	36.80	37.50	34.10
MGO	22.30	22.10	25.00	24.50	24.70	24.50	23.90	23.60	23.20	24.20	25.60	23.00	24.20	25.00	26.70
CAO	-0	.01	.05	.04	.05	.04	.04	.07	.05	.07	.06	.05	.07	.04	.04
NA2O	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
K2O	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
TIO2	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
P2O5	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
MNO	.45	.56	.69	.35	.53	.45	.33	.67	.35	.35	.45	.41	.44	.44	.33
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
NIO	-0	-0	.19	.10	-0	.02	-0	-0	.02	.02	.04	.04	.06	.06	.11
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
TOTAL	102.25	102.47	97.63	99.69	97.38	101.01	99.97	99.14	98.12	97.05	98.55	97.50	96.07	98.36	98.58

CATIONS PROPORTIONS BASED ON 4 OXYGENS

SI	1.032	1.029	.986	1.009	.998	.989	.992	.988	1.063	1.012	.986	1.050	1.012	1.011	1.041
AL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FE	.996	1.006	.925	.932	.919	.974	.985	.986	.882	.915	.916	.902	.903	.898	.796
MG	.930	.922	1.084	1.038	1.071	1.035	1.021	1.019	.983	1.049	1.097	.986	1.058	1.067	1.111
CA	0	.000	.002	.001	.002	.001	.001	.002	.002	.002	.002	.002	.002	.001	.001
NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MN	.011	.013	.012	.008	.013	.011	.008	.016	.008	.009	.011	.010	.011	.011	.007
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NI	0	0	.004	.002	0	.000	0	0	.000	.000	.001	.001	.001	.001	.002
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2.969	2.971	3.014	2.991	3.002	3.011	3.008	3.012	2.937	2.988	3.014	2.950	2.988	2.989	2.957
MG/MG+FE	48.27	47.81	53.97	52.70	53.80	51.52	50.90	50.82	52.71	53.43	54.50	52.23	53.96	54.30	58.26

TABLE 3. OLIVINE COMPOSITIONS MINNESOTA HIGHWAY 1 TRAVERSE

TABLE #	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
SAMPLE #	6113 4B	6113 4B	6113 4B	5910311	5910311	910311A	5910311	5910311	5910311	5910311	5910311	6235 1A	6235 1A	6235 1A	6235 1A
SIO2	38.90	38.10	37.20	37.10	38.40	37.80	37.30	37.40	37.30	39.00	38.40	36.40	36.00	36.30	37.10
AL2O3	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
FEO	33.10	34.70	34.20	33.70	30.30	34.40	34.00	33.20	32.00	33.40	33.10	31.80	33.10	32.40	32.00
MGO	27.70	27.60	28.90	28.40	27.70	27.40	27.60	28.30	27.00	28.30	28.30	29.40	28.50	28.80	29.10
CAO	.05	.06	.05	.08	.09	.06	.11	.06	.12	.05	.08	.05	.06	.04	.05
NA2O	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
K2O	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
TIO2	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
P2O5	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
MNO	.39	.39	.42	.42	.39	.47	.46	.42	.42	.35	.26	.37	.44	.43	.39
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
NIO	-0	.16	.13	.04	.17	.11	.19	.03	-0	.03	.21	.10	.42	.13	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
TOTAL	99.13	100.90	100.91	97.74	97.05	100.24	99.66	97.41	96.84	99.13	100.35	98.12	98.52	98.15	98.34

CATION PROPORTIONS BASED ON 4 OXYGENS

SI	1.016	1.009	1.015	1.044	1.067	1.037	1.030	1.052	1.050	1.072	1.044	1.013	1.007	1.014	1.022
AL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FE	.739	.791	.786	.793	.794	.789	.795	.781	.753	.768	.753	.740	.775	.757	.737
MG	1.219	1.121	1.175	1.107	1.147	1.121	1.136	1.103	1.133	1.078	1.147	1.220	1.189	1.194	1.204
CA	.001	.002	.002	.002	.003	.002	.003	.002	.004	.001	.002	.001	.002	.001	.001
NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MN	.009	.009	.010	.010	.009	.011	.011	.010	.010	.008	.006	.009	.010	.010	.009
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NI	0	.001	.003	.001	.004	.002	.004	.001	0	.001	.005	.002	.009	.003	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2.984	2.962	2.985	2.956	2.933	2.963	2.970	2.948	2.950	2.928	2.956	2.987	2.993	2.986	2.978
MG/MG+FE	62.25	58.64	60.10	58.27	61.97	58.67	59.13	58.54	60.06	58.39	60.38	62.23	60.55	61.31	62.09

Table 4. Tabular data for Figures 4-13.

HIGHWAY 1 TRAVERSE MG/MG+FE IN OLIVINE (MOLE PERCENT)

DISTANCE	MOLE PERCENT	ID
.74	56.36	6211332
.74	57.49	6233 2A
.74	53.58	6233 2A
.74	55.59	6233 2A
.74	48.85	6233 2A
1.77	56.22	611132A
1.76	57.49	611132A
1.76	58.23	611132A
1.76	58.34	611132A
1.79	57.98	611132A
1.77	57.79	611132A
1.86	52.19	611133A
1.86	52.84	611133A
1.86	53.12	611133A
1.86	52.41	611133A
1.86	51.46	611133A
1.85	57.76	611133A
1.84	54.41	611133A
1.80	56.29	611132A
1.86	53.12	611133A
1.85	57.61	613 3A1
1.85	54.22	613 3A1
1.85	57.59	613 3A1
1.85	57.43	613 3A1
1.85	56.49	613 3A1
1.95	52.85	611134A
1.93	53.41	611134A
1.89	51.73	611134A
1.85	51.12	611134A
1.95	52.43	611134A
2.03	51.59	611136A
2.03	51.54	611136A
2.03	51.67	611136A
2.03	51.79	611136A
2.03	51.39	611136A
2.03	51.87	611136A
2.03	51.83	611136A
2.03	51.55	611136A
2.03	51.79	611136A
2.03	51.97	611136A
2.51	47.34	611137A
2.51	47.86	611137A
2.51	46.72	611137A
2.51	46.59	611137A
2.51	48.12	611137A
2.51	48.27	611137A
2.51	47.81	611137A
3.47	52.97	6111313
3.47	52.70	613 13A
3.47	53.80	613 13A
3.47	51.52	613 13A
3.47	50.93	613 13A
3.47	51.82	613 13A
3.71	52.71	61 11 1
3.71	53.43	6111 1A
3.71	54.51	6111 1A
3.71	52.23	6111 1A
3.71	53.96	6111 1A
3.71	54.39	6111 1A

```
7.28        58.26        6111134
7.28        62.25        6113 46
7.28        58.64        6113 48
7.28        60.13        6113 48
9.88        55.27        6MILE1
9.88        61.97        6 MILE2
9.88        58.67        6 MILE3
9.88        59.13        6 MILE4
9.88        56.54        6 MILE5
9.88        60.46        6 MILE6
9.88        58.39        6 MILE7
9.88        60.38        6 MILE8
```

OMIT

90 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(-.99 .291)(.063 .382)(.116 .469)(.220 .553)(.336 .634)(.457 .713)(.584 .789)(.716 .861)(.855 .932)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSORPV SUBROUTINE

NUMBER OF DATA POINTS = 71

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X

A0 = 51.26 +- .63
A1 = .80 +- .14
STANDARD ERROR = 3.27

CORRELATION COEFFICIENT R = .55501

```
***PLOTPAC  ACCOUNTING RECORD FRAME:     1= 000001      10 WORDS  (ACCOUNTING)
***PLOTPAC              .PLT    FRAME:     2= 000002     223 WORDS  (OXIDE     )    1 TIME(S)  (NORMAL )    FILE: CALCOM
```

APPENDIX III

Computer coded fracture and rock type data on drill holes in the southwestern part of the Hoyt Lakes area.

Part 1--Computer coded raw data.

Part 2--Distribution of rock types in logged drill holes listed in Part 1.

Part 3--Plots of fracture density versus depth for drill holes listed in Part 1.

Part 4--Tabular and statistical data for plots in Part 3.

Part 5--Summary of fracture and rock type data based on computer coded raw data (Part 1) from drill cores in the southwest part of the Hoyt Lakes area.

Part 6--Location of drill holes.

PART 1

THE FOLLOWING IS A LIST OF DRILL CORE DATA. EACH CORE WAS OBSERVED AND DESCRIBED CONTINUOUSLY, BUT THE DATA IS LISTED [illegible] SUMMATION OF INFORMATION OVER TEN-FOOT INTERVALS. A DISTINCTION BETWEEN OPEN FRACTURES (CLEAR EVIDENCE OF [illegible] AS SLICKENSIDES) AND CLOSED FRACTURES IS MADE AND EACH TYPE IS DIVIDED INTO THREE CATAGORIES. THE CRITERIA [illegible] IS THE ANGLE BETWEEN THE PLANE OF FRACTURE AND THE DRILL CORE AXIS. A FRACTURE WHICH IS PARALLEL TO THE CORE [illegible] IS DEFINED AS A ZERO ( ) DEGREE FRACTURE AND ONE WHICH IS NORMAL TO THE AXIS OF THE CORE IS DEFINED AS A NINETY (90) DEGREE FRACTURE. ALL FRACTURES ARE SEPARATED 1 TO 4-30, 30-60, 60-90 DEGREE GROUPS. ADDITIONAL INFORMATION ON FRACTURES INCLUDES [illegible] AND MINOR MINERALS FILLING THE FRACTURES, DATA ON ROCK TYPE INCLUDES A GENERAL ROCK CLASSIFICATION, APPROXIMATE [illegible], A LIST OF INCLUSIONS, AND A NOTE ON SULFIDE MINERALIZATION.

KEY TO SYMBOLS USED

[illegible] INCLUSIONS (COLS. BT, I OL)

[illegible] GABBRO	FL=FELSITE	PH=PERIDOTITE
[illegible]	GR=[illegible]	PY=PYROXENITE
[illegible]	[illegible]	SR=SERPENTINITE
[illegible]	OL=OLIVINE GABBRO	TR=TROCTOLITE

MINERALIZATION (COL. M)
BLANK=NO SULFIDES
S=SULFIDES PRESENT

[illegible] SIZE
[illegible]
[illegible] (-3mm.)
[illegible] GRAIN (3-1 mm.)
[illegible] GRAIN (1 mm.)

[illegible] FILLING

[illegible]	[illegible]=FE OXIDE
[illegible]	[illegible]=CALCITE
[illegible] CRYSTALLINE MINERAL	=QUARTZ
[illegible] ZEOLITE)	
[illegible]	[illegible]=BIOTITE
[illegible]	

DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE			OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
1[illegible]	-0	-0	-0	-0	-0	-0	-0										
1[illegible]	-0	-0	-0	-0	3	-0	3									13	
1[illegible]	-0	-0	-0	3	1	4	8								13	13	13
2[illegible]	-0	-0	-0	-0	-0	4	4										
21[illegible]	1	1	-0	1	-0	1	4					6	3		3		9
22[illegible]	-0	-0	-0	-0	2	4	6					6				13	136
23[illegible]	-0	-0	-0	-0	-0	1	1					6					9
24[illegible]	-0	-0	-0	-0	-0	-0	-0										
25[illegible]	-0	1	1	-0	-0	1	3						1	1			1
[illegible]	-0	-0	-0	-0	-0	2	2										13
27[illegible]	-0	1	-0	-0	2	-0	3						1			1	
28[illegible]	-0	-0	-0	-0	-0	2	2										9
[illegible]	-0	1	1	-0	-0	8	10						1	1			16
3[illegible]	-0	-0	2	-0	-0	7	9							1			16
31	-0	-0	-0	-0	1	-0	1									1	
32[illegible]	-0	-0	-0	-0	-0	-0	-0										
33[illegible]	1	-0	-0	-0	14	31	46					1				1	1
34[illegible]	-0	-0	-0	-0	-0	24	-0										1
35[illegible]	-0	-0	-0	1	6	7	15								1	1	1
36[illegible]	-0	-0	-0	-0	1	-0	1									1	
37[illegible]	-0	-0	-0	-0	-0	3	3										15
38[illegible]	-0	-0	-0	-0	-0	112	112										1
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40[illegible]	-0	-0	-0	1	3	67	71								1	1	1
41[illegible]	-0	-0	-0	-0	-0	54	71										1
42[illegible]	-0	-0	-0	-0	2	45	47									1	1
43[illegible]	-0	-0	-0	-0	-0	9	9										1
44[illegible]	-0	-0	-0	-0	-0	20	20										1
45[illegible]	-0	-0	1	-0	-0	9	10							1			13

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[illegible]	-0	-0	3	-0	-0	1	4
[illegible]	-1	-0	5	-0	-0	2	7
[illegible]	-0	-0	1	-0	-0	4	5
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[illegible]	-	-0	9	-0	-0	2	11
[illegible]	-1	1	4	-0	-0	-0	5
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[illegible]	-	3	2	-0	-0	1	6
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[illegible]	-1	2	1	-0	1	1	5
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[illegible]	-1	3	1	1	1	-0	6
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713	1	-0	-0	-0	-0	-0	1
721	1	-0	2	-0	-0	-0	3
730	-1	-0	-0	-0	1	-0	1
740	-0	-0	-0	-0	3	-0	3
750	-0	-0	1	-0	1	1	3
760	-1	1	14	-0	-0	-0	15
771	-1	3	2	-0	2	1	8
780	-0	-0	1	-0	-0	-0	1

		1			1
		1			13
		1			13
					13
		135			13
	13	123			
123	13	135		1	13
	15	12			123
1	13	123	123	1	
	135	123		13	1
	13	13	1		1
	1	12	1	1	1
	1	1		1	1
1	1			1	
1	1	1	1	1	
	1	1			
	1			1	
		1	135	1	
	15	15	12	12	
				1	1
		1			1
	1	1		1	1
	1	1		1	
13					
12		189			
				12	
				12	
		1		1	1
	12	12			
	1	1		12	1
		12			

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[illegible]	1	2	-0	-0	4	1	8
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[illegible]	1	1	-0	6	2	-0	10
[illegible]	1	3	-0	1	1	1	7
[illegible]	1	1	-0	5	3	-0	10
[illegible]	-0	3	2	3	10	4	22
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[illegible]	1	12	7	1	7	1	29
[illegible]	2	1	-0	1	2	-0	6
[illegible]	-0	1	2	-0	4	-0	7

	129		12	12	
		12	12	1	
	2	12	12		
2	219		2		
	12	12		1	
1	1		1	1	
1	1	1	1	1	
123	1	1	1	1	
193	1		1	1	
1	1	1	1	1	
		1			
1	1	1	1	1	1
1	1	1	1	1	1
1	1	1			
1	1	1	1	1	
1	1	1	1	1	1
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	1	1	1	1	1
	1	1	1	13	1
1	1			1	1
	1			12	1
		1			1
1	1		1	1	
1	1		1	1	12
1	1		1	1	
	1	1	1	12	1
		1	1		1
	13	1	1	1	1
1	1	1	1	1	
1	1	1	1	1	1
1	1		1	1	
	1	1		1	

111	-0	2	-0	2	-0	-0	4
112	-0	3	-0	-0	2	1	6
113	3	2	-1	2	2	-0	9
114	2	7	-1	3	4	1	17
115	1	5	1	2	-0	-0	9
11	1	3	1	1	-0	-0	6
117	5	9	2	3	2	-0	23
119	5	6	1	0	3	-0	25

	1		1			
	12			1	459	
1	1		1	1		
1	12		1	1	1	
1	1	1	1			
1	1	1	1			
1	1	1	1			
1	1	1	1			

C-3

DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				% OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
3	-1	-0	-1	-0	-0	-0	-0										
4	-0	1	1	-0	6	-0	8	PD	3				12	12		12	
5	-1	24	3	-0	12	-0	42	PD	3				1	1		1	
6	1	7	5	1	3	4	22	PD	3			123	123	123	12	12	12
7	1	13	6	1	1	-0	22	PD	3			1	12	1	1	2	
8	-1	28	5	0	11	1	55	PD	1			1	12	12	12	12	1
9	1	25	8	2	6	-0	42	PD	1			1	123	12	1	12	
10	1	9	4	-0	1	1	19	PD	1			1	12	12		1	1
11	6	20	8	4	2	1	43	PD	1			12	13	123	12	13	1
12	4	8	4	2	6	2	30	PD	1			123	12	21	12	124	1
13	4	6	2	1	-0	-0	13	PD	1			12	123	123	12		
14	1	1	4	-0	-0	-0	6	PD	1			12	123	123			
15	1	7	2	-0	1	-0	11	PD	1			13	123	1		1	
16	1	6	4	-0	-0	-0	9	PD	1			1	12	123			
17	1	5	-1	1	-0	-0	7	PD	1			1	1		1		
18	2	11	-1	-0	6	-0	19	PD	1			13	1			1	
19	-1	5	1	-0	5	3	14	PD	1				1	1		1	1
20	-0	1	-0	-0	-0	-0	1	PD	1				1				
21	-1	4	-1	1	3	-0	8	PD	1				1		1	1	
22	2	4	-0	-0	3	-0	9	PD	1			1	12			12	
23	-1	5	1	-0	-0	-0	6	PD	1				1	1			
24	-0	3	1	-0	1	-0	5	PD	1				1	1		1	
25	-0	1	-0	-0	-0	-0	1	PD	1				1				
26	1	2	2	-0	-0	-0	5	PD	1			1	1	1			
27	2	3	1	-0	1	-0	7	PD	1	PY		1	1	1		1	
28	-0	4	1	-0	-0	-0	5	PD	1				1	1			
29	-1	1	1	-0	1	-0	3	PD	1				1	1		1	
30	1	3	-0	-0	-0	-0	4	PD	1			1	1				

| | | |

DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
70	-	-0	-0	-0	-0	-0	-0										
80	-	1	5	-0	-0	2	6	TR	3	PD	2		12				1
90	1	9	14	5	9	8	46	TR	3	PD	2	1	1	12	1	12	23
100	-	3	5	5	14	20	47	TR	3	PD	2	1	1	12	1	12	23
110	-	11	2	-0	5	16	34	TR	3	PD	2		12	12		12	12
120	-	1	3	-0	-0	14	13	TR	3	PD	2		12	124			12
130	-	4	8	-0	-0	4	19	TR	3	PD	2	1	123	12			12
140	-	4	4	-0	-0	1	9	TR	3	PD	2		126	126			1
150	1	3	-0	-0	-0	-0	4	TR	3	PD	2	16	126				
160	-0	2	1	-0	-0	-0	3	TR	3	PD	2		1	1			
170	-	2	1	-0	2	-0	5	TR	3	PD	2		1	1		1	
180	-	1	-0	-0	-0	-0	1	TR	3	PD	2		16				
190	-	3	3	4	2	-0	12	TR	3	PD	2		123	16	1	1	
200	-0	3	-0	-0	8	1	12	TR	3	PD	2		16			14	1
210	-0	-0	2	-0	1	3	6	TR	3	PD	2			126			1 16
220	-	4	1	-0	-0	1	6	TR	3	PD	2		1236	6			1
230	1	2	1	7	17	-0	28	TR	3	PD	2	HF		16	12	14	124
250	-0	1	-0	2	8	2	13	TR	3	PD	2	HF	1			1	124 1
260	4	14	1	2	9	3	32	TR	3	PD	2	HF	1	12	1	1	1 1
270	4	20	7	2	8	-0	41	PD	1	AN			12	12	1	1	
280	-0	4	-0	-0	6	1	11	PD	1	AN				14			1 1
290	1	1	1	1	10	-0	14	PD	1	AN			1	1	1	1	1
300	6	5	-0	-0	-0	-0	11	PD	1	AN			1	1			
310	5	8	1	-0	-0	-0	14	TR	2				1	12	1		
320	2	10	-0	-0	-0	-0	12	PD	2				1	13			
330	2	2	-0	-0	4	1	9	HF	1				12	12		12	12
340	1	1	-0	5	1	-0	8	HF	1				1	1		1 1	
													1	12	1	1 1	

| | | |

DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE			OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M INCL	0-30	30-60	60-90	0-30	30-60	60-90
[illegible]	-1	-0	-0	-0	-0	-0	-0									
9[illegible]	4	4	-0	5	2	-0	15				1	1		1	13	
10[illegible]	-1	4	-0	-0	4	-0	8					1			1	
11[illegible]	-0	4	-0	1	-0	1	6					1		1		1
12[illegible]	-0	1	-0	-0	-0	1	2					1				1
13[illegible]		3	-0	4	-0	-0	9				1	19		1		
14[illegible]	2	5	2	-0	-0	-0	-0				19	1	1			
15[illegible]	-1	4	4	1	-0	-0	9					1	1	1		
16[illegible]	1	2	1	-0	-0	-0	5				1	1	1			
17[illegible]	1	1	-0	-0	-0	-0	6				1	1				
18[illegible]	-0	3	-0	2	-0	1	6					1		1		1
19[illegible]	1	1	-0	-0	-0	-0	2				1	1				
20[illegible]	-1	1	-0	-0	-0	-0	-0					1				
21[illegible]	-1	1	-1	1	1	-0	3					1		1	1	
22[illegible]	-1	-0	1	-0	-0	-0	1						1			
23[illegible]	-0	1	-0	-0	5	-0	6					1			1	
24[illegible]	-0	1	-0	-0	-0	-0	1					1				
25[illegible]	-1	1	-0	-0	-0	-0	1					1				
26[illegible]	-0	1	-0	-0	1	-0	2					1			1	
27[illegible]	-0	3	-0	1	-0	-0	4					1		1		
28[illegible]	-0	1	-0	1	3	-0	5					1		1	1	
29[illegible]	-1	3	-0	1	-0	-0	4					1		1		
30[illegible]	-0	-0	1	-0	4	-0	5						1		1	
31[illegible]	2	1	-1	-0	-0	-0	3				1	1				
32[illegible]	2	-0	2	1	-0	1	6				1		1	1		1
33[illegible]	2	-0	1	-0	-0	-0	3				16		1			
34[illegible]	1	2	-0	2	-0	1	6				1	1		1		1
35[illegible]	2	2	-0	-0	-0	-0	4				9	19				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				1	1				

[illegible]	1	6	-0	1	2	1	11
71[illegible]	-0	2	-0	-0	1	1	4
72[illegible]	2	1	1	-0	-0	-0	4
73[illegible]	1	1	-0	-0	2	-0	4
74[illegible]	1	10	1	-0	1	-0	13
75[illegible]	-0	2	-0	-0	-0	-0	2
76[illegible]	2	4	5	-0	-0	3	14
77[illegible]	-0	6	7	1	21	4	39
78[illegible]	-0	3	2	-0	10	-0	15
79[illegible]	1	5	3	-0	3	-0	12
80[illegible]	-0	2	2	-0	64	4	72
[illegible]	1	3	4	-0	81	1	90
82[illegible]	-0	1	2	-0	55	1	59
83[illegible]	-0	3	-0	-0	33	-0	36
[illegible]	-0	2	-0	-0	41	-0	43
85[illegible]	-0	-0	-0	-0	46	4	50
86[illegible]	-0	-0	2	1	62	-0	65
87[illegible]	-0	1	-0	2	43	4	50
88[illegible]	-0	-0	-0	3	33	1	37
89[illegible]	-0	2	-0	-0	38	-0	40
90[illegible]	-0	1	-0	-0	25	-0	26
91[illegible]	-0	-0	1	3	33	1	38
92[illegible]	-0	1	-0	-0	81	-0	82
94[illegible]	-0	2	-0	-0	55	1	58
95[illegible]	-0	-0	-0	-0	29	4	33
96[illegible]	-0	-0	-0	6	8	1	15
97[illegible]	-0	-0	-0	-0	13	1	14
98[illegible]	-0	-0	-0	1	8	1	10
99[illegible]	-0	-0	-0	6	5	-0	11
100[illegible]	-0	-0	-0	4	5	1	10
101[illegible]	-0	-0	-0	5	7	-0	12
102[illegible]	-0	-0	-0	2	16	1	20

16	16		16	16	16	
	1			1	1	
1	16	16				
16	16			16		
1	163			1		
	1					
1	1	1			1	
	1	1	1	1	1	
	1	1		1		
1	1	1		1		
	1	1		1	1	
1	1	1		1	1	
	1	1		1	1	
	1			13		
	1			1		
				13	1	
		1	1	1		
	1		1	1	1	
			1	1	1	
	1			1		
	1			1		
		1	1	1	1	
	1			1		
	1			1	1	
				1	1	
			1	1	1	
				1	1	
			1	1	1	
				1	1	
			15	1	1	
			1	1		
			1	1	1	

1140	-0	1	-0	2	9	2	14		1		1	1	1	
1150	-	-0	-0	1	7	-0	80				1	1		
1160	-0	-0	1	1	2	1	5			9	1	1	1	
117	-	-0	-0	4	6	2	12				1	1	1	
1180	-0	-0	1	1	7	-0	9			1	1	1		
1190	-0	-0	1	3	12	-0	16			14	1	1		
1200	-0	-0	-0	-0	8	5	13					1	12	
1210	-0	-0	-0	-0	11	7	18					13	13	
1220	-0	-0	-0	1	5	4	10				1	1	1	
1230	1	-0	-0	1	3	5	10	1			1	1	1	
1240	2	-0	1	1	3	1	8	1		1	1	1	1	
1250	-0	-0	-0	3	3	-0	6				1	1		
1260	-0	-0	-0	1	3	3	7				1	1	1	
1270	1	-0	1	2	2	-0	6	1		1	1	1		
1280	-0	-0	-0	-0	3	-0	3					1		
1290	1	-0	-0	1	2	-0	4	1			1	1		
1300	-0	-0	-0	-0	-0	-0	-0							
1310	-0	1	-0	-0	6	-0	7		1			1		
1320	-0	-0	2	-0	-0	2	4			1			1	
1330	-0	3	2	1	7	-0	13		1	19	1	1		
1340	2	7	-0	-0	1	1	11	1	169			1	1	
1350	-0	4	3	-0	1	-0	8		19	19		1		
1360	3	2	-0	-0	-0	-0	5	1	1					
1370	3	6	-0	-0	-0	-0	9	136	136					
1380	-0	2	1	-0	2	-0	5		1	1		1		
1390	-0	-0	3	-0	-0	-0	3			1				
1400	-0	4	3	-0	5	1	13		1	1		1	1	
1410	-0	2	2	1	4	-0	9		1	1	1	1		
1420	1	1	1	2	2	-0	7	1	1	1	1	1		
1430	2	1	1	1	1	2	8	13	1	1	1	1	1	
1440	1	4	-0	-0	5	1	14	1	1			1	1	
1450	-0	5	1	2	3	-0	11		12	1	1	1		

137	2	-0	-0	-0	-0	-0	2	1					
138	-1	1	-0	4	8	-0	12		1		1	1	
139	-1	4	-0	-0	2	-0	6		13			13	
140	-1	-0	1	-0	-0	-0	1			1			
141	1	1	-0	-0	9	-0	11	1	1			1	
142	-1	1	-0	1	-0	-0	2		1		1		
143	1	-0	-0	1	3	-0	5	1			1	1	
144	2	-0	1	-0	-0	-0	3	1		1			
145	1	2	-0	4	7	-0	14	1	1		1	1	
146	1	-0	-0	2	7	1	11	1			1	1	1
147	-1	1	1	-0	3	1	6		1	1		1	1
148	-1	-0	1	-0	6	2	9			1		1	1
149	2	1	1	3	4	-0	11	1	1	13	1	1	
150	1	3	3	1	4	1	12	1	1	13	1	1	1
151	1	7302	-0	-0	-0	-0	3	1	1				
152	1	1	1	-0	-0	-0	3	1	1	2			
153	1	2	-0	-0	-0	-0	3	1	1				
154	1	3	-0	-0	-0	-0	4	1	1				
155	2	3	4	-0	-0	-0	9	1	1	1			
156	3	3	3	-0	-0	-0	9	1	1	1			
157	-0	1	1	-0	-0	-0	2	1	1	1			
158	-1	1	1	-0	-0	-0	2		1	1			
159	-0	-0	2	-0	-0	-0	2			1			
160	-1	4	-0	-0	-0	-0	4		1				
161	1	1	1	-0	-0	-0	3	1	1	1			
162	-1	1	-0	-0	-0	-0	1		1				
163	-1	3	-0	-0	-0	-0	3		1				
164	-0	-0	-0	-0	1	-0	1					1	
165	-0	3	-0	-0	-0	-0	3		1				
166	1	2	1	-0	-0	-0	4	1	1	1			
167	-0	-0	-0	-0	-0	-0	-0						
168	2	-0	2	-0	-0	-0	4	1		1			
169							1	1					

[illegible]	1	-0	1	-0	-0	-0	2
[illegible]	1	-0	-0	-0	-0	-0	1
[illegible]	-0	-0	-0	-0	-0	-0	-0
[illegible]	-0	-0	-0	-0	-0	-0	2
[illegible]	-0	-0	-0	-0	-0	-0	-0
[illegible]	-0	1	-0	-0	-0	-0	3
[illegible]	-0	-0	-0	-0	-0	-0	2

1		1
1		
1		
	1	1
		1

DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	H	INCL	0-30	30-60	60-90	0-30	30-60	60-90
70	-0	-0	-0	-0	-0	-0	-0										
80	-0	-0	1	1	-0	-0	2	AN	3	TR	3			1	1		
90	-0	-0	1	1	-0	-0	2	AN	3	TR	3			1	1		
100	1	2	3	-0	3	-0	9	AN	3	TR	3	1	1	1		1	
110	-	5	2	-0	5	2	14	AN	3	TR	3			1	1	1	1
120	2	12	1	5	7	14	54	AN	3	TR	3	1	1	1	1	1	1
130	2	4	4	4	5	8	28	AN	3	TR	3	1	1	1	1	1	1
140	-0	10	6	5	19	10	50	AN	3	TR	3		1	1	1	1	1
150	-0	-0	-0	-0	14	70	84	TR	3	PC						1	1
160	1	1	-0	-0	5	75	82	TR	3	PC			1			1	1
170	-0	1	1	-0	5	84	91	TR	3	PC			1	1		1	1
180	-0	-0	-0	1	2	37	40	TR	3	PC					1	1	1
190	-0	-0	-0	-0	4	78	82	TR	3	PC					1	1	14
200	-0	-0	-0	-0	1	55	56	TR	3	PC						1	3
210	-0	-0	-0	-0	-0	35	35	TR	3	PC							1
220	-0	-0	-0	-0	1	24	25	TR	3	PC						1	1
230	-0	-0	-0	-0	1	16	17	OL	3	PY	S					1	1
240	-0	-0	-0	2	-0	4	6	OL	3	PY					1		1
250	-0	-0	-0	-0	-0	10	10	OL	3	PY							1
260	-0	-0	-0	-0	2	1	3	OL	3	PY						13	1
270	1	-0	-0	2	1	3	7	OL	3	PY		1			1	12	1
280	-0	2	-0	1	-0	5	8	OL	3	PY			12		1		1
290	-0	-0	-0	-0	1	11	12	OL	3	PY						1	1
300	-0	-0	-0	-0	-0	8	8	OL	3	PY							1
310	-0	-0	1	-0	-0	4	5	OL	3	PY				1			12
320	-0	-0	-0	1	3	20	24	OL	3	PY					1	1	13
330	-0	-0	1	2	-0	16	19	OL	3	PY				1	12		13
340	1	-0	1	1	2	6	11	OL	3	PY		1		1	1	12	13
350	-0	-0	-0	-0	-0	3	3	OL	3	PY							1

35	-0	-0	-0	-0	-0	4	4	OL	3	PY											123
4	-1	-0	-0	-0	-0	3	3	OL	3	PY											1
37	1	1	-0	-0	1	2	5	OL	3	PY											1
38	-1	-0	-0	-0	3	10	13	OL	3	PY									1		1
39	-0	-0	-0	-0	-0	6	6	OL	3	PY											1
40	-0	-0	-0	-0	-0	14	14	OL	3	PY											1
41	-0	-0	-0	-0	1	9	10	OL	3	PY									1		1
42	-0	-0	-0	-0	1	3	4	OL	3	PY									1		1
43	-0	-0	-0	-0	4	8	12	OL	3	PY									1		12
44	-	1	1	2	1	1	6	OL	3	PY			1		1		1		1		1
45	-0	3	1	5	1	1	11	OL	3	PY			1		1		1		1		1
46	-0	3	-0	2	-0	1	6	OL	3	PY			1				13				1
47	4	5	2	-0	2	3	16	TR	3	PD	S	1	1		1				1		1
48	2	5	-1	3	4	1	15	TR	3	PD	S	1	3				1		1		1
49	1	3	-1	1	-0	-0	5	TR	3	PD	S	1	1				1				
50	1	-0	-0	1	6	-0	8	TR	3	PD	S						1		1		
51	-0	-0	-0	-0	6	-0	6	TR	3	PD	S								1		
52	-0	3	-0	1	8	1	14	TR	3	PD	S		1				1		1		1
53	1	1	-1	1	1	-0	4	TR	3	PD	S	1	1				1		1		
54	-0	-0	-0	-0	2	-0	2	TR	3	PD	S								1		
55	1	1	-1	-0	3	-0	5	TR	3	PD	S	1	1						1		
56	2	-0	-0	2	-0	-0	4	TR	3	PD	S	1					1				
57	-1	1	-0	1	5	-0	7	TR	3	PD	S		1				1		1		
58	-1	-0	-0	1	2	-0	3	TR	3	PD	S						1		1		
59	-0	-0	-0	15	-0	-0	15	TR	3	PD	S						1				
60	-0	-0	-0	43	8	-0	51	TR	3	PD	S						1		1		
61	-1	1	-0	5	7	-0	13	TR	3	PD	S		1				1		1		
62	-0	-0	-0	3	-0	-0	3	TR	3	PD	S						1				
63	-1	1	-0	3	2	-0	7	TR	3	PD	S		1				1		1		
64	-1	-0	-0	4	3	-0	7	TR	3	PD	S						1		1		
65	-0	-0	-0	2	3	-0	5	TR	3	PD	S						1		1		
66	-0	-0	1	1	7	25	34	TR	3	PD	S				1		1		1		1
67	1	-0	-0	3	1	4	11	TR	3	PD	S	1					1		1		1

	[illegible]	-0	-0	-0	4	4	11	19	TR	3	PD	S		
	691	-0	1	-0	11	10	5	27	TR	3	PD	S		
	70[illegible]	-1	1	-0	2	13	11	27	TR	1				
	71[illegible]	-0	-0	-0	5	12	7	24	TR	1				
	72[illegible]	1	-0	-0	7	5	4	17	TR	1				
	73[illegible]	-0	-0	-0	11	9	5	25	TR	1				
	74[illegible]	-0	-0	-0	6	11	6	23	TR	1				
	75	-0	-0	-0	3	5	-0	8	TR	1				

											1	1	1	
										1	1	1	1	
									1		1	1	1	
											1	1	1	
								1			1	1	1	
											1	1	1	
											1	1	1	
											1	1		

DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE			OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
10	-0	-0	-0	-0	-0	-0	-0										
[illegible]	-0	-0	-0	1	1	-0	2										
[illegible]	-0	-0	-0	8	1	-0	9										
[illegible]	-	1	-0	-0	-0	-0	1										
[illegible]	-0	-0	-0	1	-0	-0	1								1		
[illegible]	-0	-0	-0	1	9	-0	10										
[illegible]	-0	-0	-0	1	3	-0	4										
[illegible]	-0	-0	-0	-0	3	-0	3										
[illegible]	-0	-0	-0	2	6	-0	8										
[illegible]	-0	-0	-0	2	2	1	5								13		
[illegible]	-0	-0	-0	3	1	-0	4										
[illegible]	-0	-0	-0	1	1	-0	2								1		
[illegible]	-	-0	-0	-0	-0	-0	-0										
[illegible]	-0	-0	-0	1	1	-0	2										
[illegible]	-0	-0	-0	3	5	-0	8										
[illegible]	-0	-0	-0	4	4	-0	8								3	3	
[illegible]	-0	-0	-0	4	-0	-0	4										
[illegible]	-0	-0	-0	4	4	-0	8										
[illegible]	-0	-0	-0	8	-0	-0	8										
[illegible]	-0	-0	-0	-0	2	-0	2										
[illegible]	-0	-0	-0	1	-0	-0	1										
[illegible]	-0	-0	-0	1	-0	-0	1										
[illegible]	-0	-0	-0	2	1	-0	3										
240	-0	-0	-0	6	6	1	13								3	13	
[illegible]	-0	-0	-0	6	1	-0	7									3	
[illegible]	-0	-0	-0	-0	9	-0	9										
[illegible]	-0	-0	-0	-0	-0	-0	-0										
[illegible]	-0	-0	-0	-0	1	-0	1										
[illegible]	-0	-0	-0	1	5	-0	6								13	13	

30	-0	-0	-0	1	-0	-0	1
31	-0	-0	-0	1	-0	1	2
32	-0	-0	-0	-0	-0	1	1
33	-0	-0	-0	-0	-0	-0	-0
34	-0	-0	-0	4	1	-0	5
35	1	-0	-0	5	1	-0	7
36	-0	1	-0	4	1	-0	6
37	-0	-0	-0	1	1	-0	2
38	-0	-0	-0	2	-0	1	3
39	-0	-0	-0	6	-0	-0	6
40	-0	1	-0	1	-0	-0	2
41	-0	-0	-0	3	2	-0	5
42	-0	-0	-0	2	1	1	4
43	-0	1	-0	11	3	1	16
44	-0	-0	-0	5	-0	1	6
45	-0	-0	-0	1	1	3	5
46	-0	-0	-0	5	1	-0	6
47	-0	-0	-0	4	-0	-0	4
48	-0	-0	-0	-0	1	-0	1
49	-0	-0	-0	4	3	-0	7
50	-0	-0	-0	5	1	2	9
51	-0	-0	-0	2	5	-0	7
52	-0	-0	-0	3	-0	10	13
53	-0	-0	-0	3	3	3	9
54	-0	-0	-0	2	2	1	5
55	-0	-0	-0	2	1	-0	3
56	-0	-0	-0	1	3	-0	4
57	-0	-0	-0	2	-0	-0	2
58	-0	-0	-0	-0	-0	-0	-0
59	-0	-0	-0	1	2	-0	3
60	-0	-0	-0	-0	-0	-0	-0
61	-0	-0	-0	1	2	1	4
62	-0	-0	-0	-0	1	-0	1

13

1

1

13

1

1

1 1

1 13 1

1

| | | |

[illegible]	-0	-0	-0	-0	-0	1	1							1	
[illegible]	-0	-0	-0	-0	1	-0	1						1		
[illegible]	-0	-0	-0	-0	-0	1	1							1	
[illegible]	-0	-0	-0	-0	-0	-0	-0								
[illegible]	-0	-0	-0	1	-0	-0	1								
1[illegible]	-0	-0	-0	1	3	-0	4						89		
1[illegible]	-0	-0	-0	3	-0	7	10					13		13	
1[illegible]	-0	-0	-0	3	4	3	10						8		
1[illegible]	-0	-0	-0	6	5	1	12								
1[illegible]	-0	1	-0	3	5	2	11					4			
1[illegible]	-0	1	-0	2	2	8	13								
1[illegible]	-0	-0	-0	-0	-0	16	16								
1[illegible]	-0	-0	-0	-0	-0	4	4								
1[illegible]	-0	-0	-0	-0	3	8	11								
11[illegible]	-0	-0	-0	-0	-0	6	6							1	
111	-0	-0	-0	-0	-0	-0	-0								
11[illegible]	-0	-0	-0	-0	-0	5	5							1	
1[illegible]	-0	-0	-0	-0	-0	1	1							4	
11[illegible]	1	-0	-0	-0	1	5	7								
11[illegible]	-0	-0	-0	-0	-0	-0	-0								
11[illegible]	-0	-0	-0	2	1	-0	3					13	1		
1[illegible]	-0	-0	-0	3	5	4	12					13	1	13	
11[illegible]	-0	-0	-0	1	5	3	9					1	1	1	
11[illegible]	-0	2	-0	6	13	-0	21					1	13		
120[illegible]	1	-0	-0	2	11	7	21		1			1	13	1	
121[illegible]	1	-0	-0	3	2	-0	6		1			1	13		
122	-0	1	-0	1	9	-0	11			1		3	1		
123[illegible]	-0	-0	-0	-0	6	1	7						1	1	
124[illegible]	-0	-0	1	-0	5	4	10			1			1	1	
125[illegible]	1	-0	-0	-0	3	2	6		1				1	1	
126[illegible]	-0	-0	-0	1	3	1	5					1	1	1	
127[illegible]	3	3	1	2	14	6	31		1	1	1	1	1	1	
128[illegible]	-0	-0	-0	2	3	3	31					1	1	1	

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2271	1	-0	-0	3	4	9	17
22-	-1	-0	-0	2	12	10	24
2[illegible]	-0	-0	-0	2	2	5	9
2203	-1	-0	-0	2	17	12	31

1	1	1	1
	1	1	1
	1	1	1
	1	1	1

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DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
16[illegible]	-0	-0	-0	-0	-0	-0	-0										
17[illegible]	-0	-0	-0	11	1	30	42	TR	2		HF				1	1	13
18[illegible]	-0	-0	-0	10	2	26	38	TR	2		HF				1	1	1
19[illegible]	-0	-0	-0	4	4	27	35	TR	2		HF				1	1	1
20[illegible]	-0	-0	-0	21	25	34	81	TR	2		HF				1	1	1
21[illegible]	-0	-0	-0	24	15	14	53	TR	2		HF				1	1	1
22[illegible]	-0	-0	-0	3	5	7	15	TR	2		HF				1	1	1
23[illegible]	-0	-0	-0	16	7	16	39	TR	2		HF				1	1	13
24[illegible]	-0	-0	-0	2	3	10	15	TR	2		HF				1	1	1
25[illegible]	-0	-0	-0	3	1	1	5	TR	2		HF				1	1	1
26[illegible]	-0	-0	-0	-0	3	9	12	TR	2		HF				1	1	
27[illegible]	-0	-0	-0	5	5	2	12	TR	2		HF				1	1	1
28[illegible]	-0	-0	-0	5	4	3	12	TR	2		HF				1	1	1
29[illegible]	-0	-0	-0	3	2	11	16	TR	2		HF				1	1	1
30[illegible]	-0	-0	-0	4	6	9	19	TR	2		HF				1	1	1
31[illegible]	-0	-0	-0	2	4	2	8	TR	2		HF				1	1	1
32[illegible]	-0	-0	-0	4	3	9	16	TR	2		HF				1	1	1
33[illegible]	-0	-0	-0	2	5	10	17	TR	2		HF				1	1	1
34[illegible]	-0	-0	-0	7	4	5	16	TR	2		HF				1	1	1
35[illegible]	-0	-0	-0	2	1	3	6	TR	2		HF				1	1	1
36[illegible]	-0	-0	-0	1	-0	6	7	TR	2		HF				1		1
37[illegible]	-0	-0	-0	2	5	5	10	TR	2		HF				1	1	1
38[illegible]	-0	-0	-0	3	9	16	29	TR	2		HF				1	1	1
39[illegible]	-0	-0	-0	-0	-0	-0	12	TR	2		HF						
40[illegible]	-0	-0	-0	1	3	5	9	TR	2		HF				1	1	1
41[illegible]	-0	-0	-0	5	4	9	18	TR	2		HF				1	1	1
42[illegible]	-0	-0	-0	-0	-0	-0	-0	TR	2		HF						
43[illegible]	-0	-0	-0	4	3	4	11	TR	2		HF				1	1	1
44[illegible]	-0	-0	-0	-0	-0	-0	-0	TR	2		HF						

	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE			OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	HT	M	0-30	30-60	60-90	0-30	30-60	60-90
2	0	0	0	0	0	0	0									
3	0	0	1	2	4	1	8	TR	I	AN				1	12	1
4	0	0	0	0	1	0	1	TR	I	AN					2	12
5	0	0	0	0	4	3	7	TR	I	AN					1	13
6	0	1	0	2	3	0	6	TR	I	AN		1		1	1	
7	0	0	1	3	7	5	17	TR	I	AN		1	1	1	1	1
8	0	0	0	0	1	3	4	TR	I	AN					1	4
9	0	0	0	1	4	1	6	TR	I	AN				1	1	1
10	0	0	0	1	2	1	10	TR	I	AN				1	1	1
11	0	0	0	2	1	0	3	TR	I	AN				1	1	
12	0	0	0	0	0	0	0	TR	I	AN						
13	0	0	0	1	0	1	2	TR	I	AN				1		1
14	0	0	0	3	0	1	4	TR	I	AN				1		1
15	0	1	0	0	4	7	12	TR	I	AN		1			1	4
16	0	1	0	1	0	3	5	TR	I	AN		12		1		1
17	0	0	0	0	3	2	5	TR	I	AN					1	4
18	0	0	0	0	2	2	4	TR	I	AN					1	12
19	0	0	0	0	2	0	2	TR	I	AN					1	1
20	0	0	0	1	1	5	7	TR	I	AN				1	12	1
21	0	0	0	0	7	7	14	TR	I	AN					1	1
22	0	0	0	0	5	3	8	TR	I	AN					1	1
23	0	0	0	3	6	3	12	TR	I	AN				1	13	1
24	0	0	0	2	0	0	2	TR	I	AN				1		
25	0	0	0	0	3	0	3	TR	I	AN					12	
29	0	0	0	0	3	2	4	TR	I	AN				13	1	1
27	0	0	0	0	0	3	3	TR	I	AN						1
28	0	0	0	0	1	2	3	TR	I	AN					13	1
29	0	1	0	0	0	0	1	TR	I	AN		13				
30	0	0	0	1	0	1	2	TR	I	AN				19		1

DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE			OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M INCL	0-30	30-60	60-90	0-30	30-60	60-90
2	-0	-0	-0	-0	-0	-0	-0									
3[illegible]	-0	-0	-0	1	1	-0	2	TR	3							
[illegible]	-0	-0	-0	-0	5	1	6	TR	3							
5[illegible]	-0	-0	-0	-0	5	3	8	TR	3							
[illegible]	-0	-0	-0	-0	-0	3	3	TR	3							
7[illegible]	1	-0	-0	-0	1	2	4	TR	3							
[illegible]	-0	-0	-0	-0	4	3	7	TR	3							
[illegible]	-0	-0	-0	-0	3	5	8	TR	3							
[illegible]	-0	-0	-0	-0	6	2	8	TR	3							
11[illegible]	-0	-0	-0	-0	6	1	7	TR	3							
[illegible]	-0	-0	-0	1	3	4	8	TR	3					10		
13[illegible]	-0	-0	-0	-0	3	2	5	TR	3							
[illegible]	-0	-0	1	1	-0	5	7	TR	3							
15[illegible]	-0	-0	-0	-0	2	4	6	TR	3							
16[illegible]	-0	-0	-0	-0	4	3	7	TR	3						1[illegible]	
17[illegible]	-0	-0	-0	-0	2	8	10	TR	3							
18[illegible]	-0	-0	-0	-0	-0	2	2	TR	3							
19[illegible]	-0	-0	-0	-0	3	3	6	TR	3							
20[illegible]	-0	-0	-0	-0	4	-0	4	TR	3							
21[illegible]	-0	-0	-0	-0	4	3	7	TR	3							
22[illegible]	-0	-0	-0	-0	2	8	10	TR	3							
23[illegible]	-0	-0	1	1	3	14	19	TR	3							
24[illegible]	-0	-0	-0	-0	-0	15	15	TR	3							
25[illegible]	-0	-0	-0	1	2	10	13	TR	3							
26[illegible]	-0	-0	-0	-0	3	3	6	TR	3							
27[illegible]	-0	-0	-0	-0	3	5	8	TR	3							
28[illegible]	-0	-0	-0	-0	4	3	7	TR	3							
29[illegible]	-0	-0	-0	-0	6	1	7	TR	3							
30[illegible]	-0	-0	-0	-0	11	3	14	TR	3							

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670	-0	-0	-0	-0	-0	-0	-0	TR	3				
680	-0	-0	-0	-0	-0	-0	-0	TR	3				
690	-0	-0	-0	1	1	-0	2	TR	3		1	1	
700	-0	-0	-0	-0	3	-0	3	TR	3			1	
710	-0	-0	-0	-0	3	2	5	TR	3			1	1
720	-1	-0	-0	-0	8	7	15	TR		S ANPDHF		1	1
730	-0	-0	-0	-0	6	7	13	TR		S ANPDHF		1	1
740	-0	-0	-0	1	13	3	17	TR		S ANPDHF	1	1	1
750	-0	-0	-0	-0	10	5	15	TR		S ANPDHF		1	1
760	-0	-0	-0	4	7	4	15	TR		S ANPDHF	1	1	1
770	-0	-0	-0	-0	3	-0	3	TR		S ANPDHF		1	
780	-0	-0	-0	2	2	-0	4	TR		S ANPDHF	1	1	
790	-1	-0	-0	-0	3	1	4	TR		S ANPDHF		1	1
800	-1	-0	-0	3	15	4	22	TR		S ANPDHF	1	1	1
810	-1	-0	-0	2	5	10	18	TR		S ANPDHF	1	1	1
820	-1	-0	-0	3	8	5	16	TR		S ANPDHF	1	13	1
830	-0	-0	-0	-0	4	6	10	TR		S ANPDHF	1	13	1
840	-0	-0	-0	-0	4	4	8	TR		S ANPDHF		1	1
850	-0	-0	-0	1	4	5	10	TR		S ANPDHF	1	1	1
860	-1	-0	-0	-0	2	2	4	TR		S ANPDHF		1	1
870	-0	-0	-0	-0	3	7	10	TR		S ANPDHF		1	1
880	-0	-0	-0	-0	7	3	10	TR		S ANPDHF		13	1
890	-0	-0	-0	1	7	2	10	TR		S ANPDHF	1	1	1
900	-0	-0	-0	3	5	4	12	TR		S ANPDHF	1	1	1
910	-0	-0	-0	-0	-0	13	13	TR		S ANPDHF			1
920	-0	-0	-0	-0	2	3	5	TR		S ANPDHF		1	1
930	-0	-0	-0	-0	7	6	13	TR		S ANPDHF		1	1
940	-1	-0	-0	5	12	13	30	TR		S ANPDHF	1	1	1
950	-1	-0	-0	3	5	5	13	TR		S ANPDHF	1	13	1
960	-0	-0	-0	6	13	6	25	TR		S ANPDHF	1	1	1
970	-0	-0	-0	3	5	4	12	TR		S ANPDHF	1	13	1
980	2	-0	-0	3	4	5	14	TR		S ANPDHF	1	1	1
990	-0	-0	-0	-0	2	1	3	TR		S ANPDHF		1	1

99	1	-0	-0	1	3	2	3	TR	S ANPDHF	3			1	1	1
100	-0	-0	-0	5	2	5	12	TR	S ANPDHF				1	1	1
101	-0	-0	-0	-0	2	1	3	TR	S ANPDHF					1	1
102	2	1	-0	4	7	-0	14	TR	S ANPDHF	1	1		1	1	
103	1	-0	-0	1	5	7	14	TR	S ANPDHF	1			1	1	1
104	-0	-0	-0	10	5	1	16	TR	S ANPDHF				1	1	1
105	1	-0	-0	5	7	3	16	TR	S ANPDHF	1			1	1	1
106	1	-0	-0	8	19	10	38	TR	S ANPDHF	1			1	1	13
107	-0	2	-0	11	46	4	63	TR	S ANPDHF		1		1	1	13
108	1	-0	-0	9	24	4	38	TR	S ANPDHF	1			1	13	1
109	1	-0	-0	5	3	1	10	TR	S ANPDHF	1			1	1	1
110	-0	-0	-0	4	6	10	20	TR	S ANPDHF				1	1	1
111	-0	-0	-0	9	19	7	34	TR	S ANPDHF				1	1	1
112	-0	-0	-0	13	24	2	39	TR	S ANPDHF				1	1	1
113	2	-0	-0	12	21	3	38	TR	S ANPDHF	1			1	1	1
114	2	2	-0	2	5	-0	11	TR	S ANPDHF	1	1		1	1	

A3-3

DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
50	-0	-0	-0	-0	-0	-0	-0										
60	-0	-0	-0	3	5	2	10								1	1	1
70	-0	-0	-0	2	42	3	47								1	1	1
80	-0	-0	-0	1	36	4	41								1	1	1
90	-0	-0	-0	0	28	3	32								1	1	1
100	-0	-0	-0	13	40	15	68								1	1	1
110	-0	-0	-0	27	59	29	115								14	14	14

DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE			OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M INCL	0-30	30-60	60-90	0-30	30-60	60-90
2[illegible]	-0	-0	-0	-0	-0	-0	-0									
3[illegible]	-0	-0	-0	3	3	5	11	TR ?		S				1	1	1
4[illegible]	-0	-0	-0	1	3	8	12	TR ?		S				1	1	1
5[illegible]	-0	-0	-0	-0	3	6	9	TR ?		S				1	1	1
6[illegible]	-0	-0	-0	10	12	14	36	TR ?		S				1	1	1
7[illegible]	-0	-0	-0	10	14	4	28	TR ?		S				1	1	1
8[illegible]	-0	-0	-0	14	22	9	45	TR ?		S				1	1	1
9[illegible]	-0	-0	-0	6	5	2	13	TR ?		S				13	1	1
10[illegible]	-0	-0	-0	17	12	2	32	TR ?		S				1	1	1
11[illegible]	-0	-0	-0	15	14	6	35	TR ?		S				1	1	1
12[illegible]	-0	-0	-0	14	8	3	25	TR ?		S				13	1	1
13[illegible]	-0	-0	-0	13	6	1	20	TR ?		S				17	17	1
14[illegible]	3	-0	-0	3	1	2	9	TR ?		S	17			1	17	1
15[illegible]	-0	1	-0	6	10	3	20	TR ?		S		1		17	17	17
16[illegible]	2	-0	-0	53	4	-0	59	TR ?			1			1	1	

See next page

26[illegible]	-0	-0	-0	4	7	3	14	TR ?		S				1	13	13
27[illegible]	1	-0	-0	14	8	4	27	TR ?		S	13			13	1	13
28[illegible]	-0	-0	-0	4	12	3	19	TR ?		S				13	1	13
29[illegible]	-0	-0	-0	13	7	6	26	TR ?		S				13	13	13
30[illegible]	-0	-0	-0	8	6	5	19	TR ?		S				1	1	1
31[illegible]	-0	-0	-0	9	6	5	20	TR ?		S				1	1	1
32[illegible]	-0	-0	-0	2	2	4	8	TR ?		S				1	1	1
33[illegible]	-0	-0	-0	5	3	6	14	TR ?		S				1	1	1
340	-0	-0	-0	7	5	2	14	TR ?		S				1	1	1
350	-0	-0	-0	4	7	-0	11	TR ?		S				1	1	
360	-0	-0	-0	4	-0	-0	4	TR ?		S				1		
37[illegible]	-0	-0	-0	5	10	3	18	TR ?		S	PD			1	1	1
38[illegible]	2	1	-0	-0	3	-0	6	TR ?		S	PD	1	1		13	
39[illegible]	1	1	-0	-0	-0	-0	-0	SE				1	1			

2

400	2	-0	-0	-0	-0	-0	-42	SE					1						
410	3	2	-0	-0	-0	-0	-45	SE					1	1					
420	-0	-0	-0	3	12	7	22	TR	3	S	PD					1	13	13	
430	-0	-0	-0	17	19	24	60	TR	3	S	PD					1	13	13	
440	-0	-0	-0	23	35	26	84	TR	3	S	PD					13	13	1	
450	-0	1	-0	3	21	31	56	TR	3	S	PD			1		1	13	1	
460	2	-0	-0	1	15	17	35	TR	3	S	PD		1			1	13	13	
470	3	-0	-0	3	12	7	26	SE					1			1	1	1	
480	-0	-0	-0	8	31	17	56	TR	3	S	PD					1	13	13	
490	-0	-0	-0	4	7	9	20									1	1	1	
500	1	1	-0	11	25	19	58	TR	3	S	PD		1	1		1	13	1	
510	-0	-0	-0	3	7	12	22	TR	3	S	PD					1	1	1	
520	-0	-0	-0	9	19	24	52	TR	2	S	PD					1	13	1	
530	-0	-0	-0	8	13	9	30	TR	3	S	PD					1	1	1	
540	1	-0	-0	22	52	20	93	TR	3	S	PD		1			1	1	1	
550	-0	-0	-0	10	29	19	58	TR	3	S	PD					1	1	1	
560	-0	-0	-0	14	41	11	66	TR	3	S	PD					1	1	1	
570	-0	-0	-0	10	50	28	88	TR	3	S	PD					1	1	1	
580	-0	-0	-0	20	65	37	122	TR	3	S	PD					1	1	1	
590	-0	-0	-0	7	48	26	83	TR	3	S	PD					1	1	1	
600	2	3	1	18	38	34	96	TR	3	S	PD		1	1	1	1	1	1	
610	4	1	-0	12	53	39	109	TR	3	S	PD		1	1		1	1	1	
620	-0	1	-0	6	40	41	88	TR	2	S				1		1	1	1	
630	-0	-0	-0	5	32	15	52	TR	2	S						1	1	1	
640	2	-0	-0	5	28	25	60	TR	2	S			1			1	1	1	
650	-0	-0	-0	6	17	7	30	TR	2	S						1	1	1	
660	-0	-0	-0	5	12	12	29	TR	2	S						1	1	1	
670	-0	-0	-0	3	20	16	39	TR	2	S						1	1	1	
680	2	-0	-0	2	18	11	33	TR	2	S			1			1	1	1	
690	2	1	-0	5	35	11	54	TR	2	S			1	1		1	1	1	
700	-0	-0	-0	32	54	15	103	TR	2		HF					1	1	1	
710	1	1	-0	19	30	6	57	TR	2		HF		1	1		12	12	12	
720	1	-0	-0	10	8	1	20	TR	2		HF		12			12	12	12	

730	-0	1	-0	5	12	3	21	TR 2	HF		1		1	14	1
170	3	-0	-0	19	14	5	41	TR 2	S	1			17	1	17
190	5	1	-0	11	6	2	27	TR 2	S	1	1		17	1	1
190	3	-0	-0	12	8	4	27	TR 2	S	1			13	1	1
200	4	-0	1	14	10	2	31	TR 2	S	1		1	13	13	1
210	-0	1	-0	6	11	2	20	TR 2	S		1		1	1	1
220	-0	-0	-0	12	6	4	22	TR 2	S				13	1	1
230	2	-0	-0	9	6	3	20	TR 2	S	13			1	1	1
240	1	-0	-0	6	3	-0	10	TR 2	S	17			1	1	
250	3	-0	-0	-0	-0	-0	3	TR 2	S	1					

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DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
40	-0	-0	-0	-0	-0	-0	-0										
50	-0	-0	-0	3	16	3	22	TR 3	AN		HF				1	1	1
60	-0	-0	-0	2	6	2	10	TR 3	AN		HF				1	1	1
70	-0	-0	-0	2	17	-0	19	TR 3	AN		HF				1	1	
80	-0	-0	-0	-0	6	1	7	TR 3	AN		HF					1	1
90	-0	-0	-0	1	6	2	9	TR 3	AN		HF				1	1	1
100	-0	-0	-0	5	9	1	15	TR 3	AN		HF				1	1	1
110	-0	-0	-0	4	2	2	8	TR 3	AN		HF				1	1	1
120	-0	-0	-0	3	9	2	14	TR 3	AN		HF				1	1	1
130	-0	-0	-0	-0	6	1	7	TR 3	AN		HF				1	1	1
140	-0	-0	-0	5	9	1	16	TR 3	AN		HF				1	1	1
150	-0	-0	-0	2	5	2	9	TR 3	AN		HF				1	1	1
160	-0	-0	-0	2	5	1	8	TR 3	AN		HF				1	1	1
170	-0	-0	-0	4	7	3	14	TR 3	AN		HF				1	1	1
180	-0	-0	-0	2	6	-0	8	TR 3	AN		HF				1	1	
190	-0	-0	-0	6	10	4	20	TR 3	AN		HF				1	1	1
200	-0	-0	-0	6	16	7	39	HF 1	TR 2						1	1	1
210	-0	-0	-0	6	12	-0	18	HF 1	TR 2						1	1	
220	-0	-0	-0	14	15	1	30	HF 1	TR 2	S					1	1	1
230	-0	-0	-0	11	11	4	26	HF 1	TR 2	S					1	1	1
240	-0	-0	-0	9	13	-0	22	HF 1	TR 2	S					1	1	
250	-0	-0	-0	4	2	1	7	HF 1	TR 2	S					1	1	1
260	-0	-0	-0	-0	2	1	3	HF 1	TR 2	S						1	1
270	-0	-0	-0	3	8	1	12	HF 1	TR 2						1	1	1
280	-0	-0	-0	-0	10	-0	10	HF 1	TR 2							1	
290	-0	-0	-0	-0	16	1	17	HF 1	TR 2							124	1
300	-0	-0	-0	4	23	3	30	HF 1	TR 2						1	1	1
310	-0	-0	-0	1	7	6	14	HF 1	TR 2						1	142	1
320	-0	-0	-0	4	9	2	15	HF 1	TR 2						1	142	1

330	-0	-0	-0	4	24	5	33	HF 1	TR 2	1	1	14
340	-0	-0	-0	5	12	7	24			1	1	1234
350	-0	-0	-0	1	25	16	42	HF 1	TR 2	1	1	1
360	-0	-0	-0	3	23	3	28	HF 1	TR 2	1	1	1
370	-0	-0	-0	4	31	13	48	HF 1	TR 2	1	1	1
380	-0	-0	-0	6	13	14	33	HF 1	TR 2	1	14	14

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DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE			OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M INCL	0-30	30-60	60-90	0-30	30-60	60-90
20	-0	-0	-0	-0	-0	-0	-0									
30	-0	-0	-0	2	40	30	12	TR 3	PD	DUPD				1	13	13
40	-0	-0	-0	3	62	52	117	TR 3	PD	DUPD				1	13	13
50	-0	-0	-0	3	41	39	83	TR 3	PD	DUPD				1	13	1
60	-0	-0	-0	1	15	41	57	TR 3	PD	DUPD				1	13	13
70	-0	-0	-0	10	24	40	74	TR 3	PD	DUPD				1	1	1
80	-0	-0	-0	4	11	18	33	TR 3	PD	DUPD				1	1	1
90	-0	-0	-0	4	12	11	27	TR 3	PD	DUPD				1	1	1
100	-0	-0	-0	3	23	12	38	TR 3	PD	DUPD				1	1	1
110	-0	-0	-0	6	11	17	34	TR 3	PD	DUPD				1	1	1
120	-0	-0	-0	1	14	10	25	TR 3	PD	DUPD				1	1	1
130	-0	-0	-0	5	17	11	33	TR 3	PD	DUPD				1	1	13
140	1	-0	-0	4	17	24	46	TR 3	PD	DUPD	1			1	1	1
150	-0	1	-0	1	7	9	18	TR 3	PD	DUPD				1	1	1
160	-0	-0	-0	3	5	4	12	TR 3	PD	DUPD				1	13	1
170	-0	-0	-0	4	9	3	16	TR 3	PD	DUPD				1	13	1
180	-0	-0	-0	2	9	15	26	TR 3	PD	DUPD				1	1	1
190	-0	-0	-0	5	6	6	17	TR 3	PD	DUPD				1	13	1
200	-0	-0	-0	2	20	14	36	TR 3	PD	DUPD				1	13	1
210	-0	-0	-0	2	14	2	18	TR 3	PD	DUPD				1	13	1
220	-0	-0	-0	1	14	3	18	TR 3	PD	DUPD				1	1	1
230	-0	-0	-0	10	26	16	52	TR 3	PD	DUPD				13	1	1
240	-0	-0	-0	4	19	5	28	TR 3	PD	DUPD				13	13	1
250	-0	-0	-0	3	21	3	27	TR 3	PD	DUPD				1	1	1
260	-0	-0	-0	1	22	8	31	TR 3	PD	DUPD				1	1	1
270	1	-0	-0	1	42	15	59	TR 3	PD	DUPD	1			1	1	1
280	-0	-0	-0	2	33	15	50	TR 3	PD	DUPD				1	13	13
290	-0	-0	-0	8	30	11	49	TR 3	PD	DUPD				1	1	1
300	-0	-0	-0	4	31	11	46	TR 3	PD	DUPD				1	1	1

| | | |

649	-0	-0	-0	8	5	6	19	TR	1	PD	S	1	1	1
653	-0	-0	-0	5	2	5	12	TR	1	PD	S	1	1	1
662	-0	-0	-0	3	4	2	9	TR	1	PD	S	1	1	1
672	-0	-0	-0	4	3	1	8	TR	1	PD	S	1	1	1
650	-0	-0	-0	10	9	6	25	TR	1	PD	S	1	1	1
693	-0	-0	-0	14	11	2	27	TR	1	HF	S	1	1	1
70[illegible]	-0	-0	-0	6	7	5	18	TR	1	HF	S	1	1	1
710	-0	-0	-0	8	13	2	23	TR	1	HF	S	1	1	1
720	1	-0	-0	9	36	1	47	TR	1	HF	S	1	1	1
730	-0	-0	-0	20	32	2	54	TR	1	HF	S	1	1	1
74[illegible]	-	-0	-	26	34	2	62	TR	1	HF	S	1	14	1
760	-0	-0	-	6	11	2	19	TR	1	HF	S	13	1	1
77[illegible]	-0	-0	-0	9	17	5	31	TR	1	HF	S	1	1	1
78[illegible]	-0	-0	-0	11	50	8	69	TR	1	HF	S	1	1	1

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DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
30	-0	-0	-0	-0	-0	-0	-0										
40	-0	-0	-0	7	2	7	16	TR	2	HF	S				1	1	1
50	-0	-0	-0	3	7	9	19	TR	2	HF	S				1	1	1
60	-0	-0	-0	1	2	7	10	TR	2	HF	S				1	1	1
70	-0	-0	-0	5	2	5	12	TR	2	HF	1				1	1	1
80	-0	-0	-0	10	7	6	23	TR	2	HF	1				1	1	1
90	-0	-0	-0	7	5	6	20	TR	2	HF	1				1	1	1
100	-0	-0	-0	5	13	6	24	TR	2	HF	1				1	1	1
110	-0	-0	-0	5	4	3	12	TR	2	HF	1				1	1	1
120	-0	-0	-0	2	6	6	14	TR	1		S	HF			1	1	1
130	-0	-0	-0	14	13	5	32	TR	1		S	HF			1	1	1
140	-0	-0	-0	18	34	9	61	TR	1		S	HF			14	1	1
150	-0	-0	-0	6	15	9	30	TR	1		S	HF			21	1	1
160	-0	-0	-0	2	8	12	22	TR	1		S	HF			1	1	1
170	-0	-0	-0	2	11	14	27	TR	1		S	HF			1	1	1
180	-0	-0	-0	5	6	28	39	TR	1		S	HF			1	1	1
190	-0	-0	-0	33	25	17	75	TR	1		S	HF			1	1	1
200	-0	1	2	13	12	10	39	TR	1		S	HF		1 12	13	1	1
210	2	-0	-0	14	10	6	32	TR	1		S	HF	123		1	1	1
220	-0	-0	-0	1	4	2	7	TR	1		S	HF			1	1	1
230	1	-0	1	4	18	4	26	TR	1		S	HF	12	1	1	1	1
240	-0	-0	-0	5	16	2	23	TR	1		S	HF			1	1	1
250	-0	-0	-0	3	8	1	12	TR	1		S	HF			1	1	1
260	1	1	-0	17	21	5	45	TR	1		S	HF		1	1	1	1
270	-0	-0	-0	7	26	39	62	TR	1		S	HF			123	123	123
280	-0	-0	-0	5	10	12	27	TR	1		S	HF			12	12	12
290	-0	-0	-0	7	10	8	25	TR	1		S	HF			12	12	12

DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
30	-0	-0	-0	2	2	-0	4	TR			FL				14	1	
40	-0	1	-0	-0	-0	-0	1	TR			FL		1				
50	-0	-0	-0	1	3	-0	4	TR			FL				1	13	
60	-0	-0	-0	-0	2	-0	2	TR			FL					3	
70	-0	-0	-0	-0	1	-0	1	TR			FL					3	
80	-0	-0	-0	-0	1	-0	1	TR			FL					1	
90	-0	-0	1	-0	-0	-0	1	TR			FL			1			
100	-0	-0	-0	1	-0	-0	1	TR			FL				1		
110	-0	-0	-0	-0	5	-0	5	TR			FL					13	
120	-0	-0	-0	2	1	-0	3	TR			FL				13	1	
130	-0	-0	-0	3	-0	1	4	TR			FL				1		1
140	-0	-0	1	-0	-0	-0	1	TR			FL			6			
150	-0	-0	-0	3	3	-0	6	TR			FL				1	13	
160	-0	-0	-0	1	6	1	8	TR			FL				1	13	1
170	-0	-0	-0	4	3	-0	7	TR			FL				1	1	
180	-0	-0	-0	1	4	1	6	TR			FL				1	13	1
190	-0	-0	-0	1	6	-0	7	TR			FL				1	13	
200	-0	-0	-0	4	13	1	18	TR			FL				14	14	14
210	-0	1	-0	8	8	3	20	TR			FL		1		14	14	14
220	-0	-0	-0	5	5	1	11	TR			FL				14	14	14
230	-0	-0	-0	16	15	2	33	TR			FL				14	14	14
240	-0	-0	-0	12	18	-0	30	TR			FL				1	1	
250	-0	-0	-0	9	5	-0	14	TR			FL				13	1	
260	-0	-0	-0	10	-0	-0	10	TR			FL				1		
270	-0	-0	-0	2	3	-0	5	TR			FL				1	1	
280	-0	-0	-0	4	4	4	12	TR			FL				14	1	1
290	-0	-0	-0	2	7	2	11	TR			FL				1	1	1
300	-0	-0	-0	3	9	4	16	TR			FL				1	1	1
310	-0	-0	-0	2	10	1	13	TR			FL				1	13	1

320	-0	-0	-0	8	2	-0	10	TR	FL				1	1	
330	-0	-0	-0	1	3	-0	4	TR	FL				3	1	
340	-0	-0	-0	5	9	-0	14	TR	FL				1	13	
350	-0	-0	-0	1	1	1	3	TR	FL				1	1	1
360	1	2	-0	-0	4	4	11	TR	FL	1	1			1	1
370	-0	1	-0	2	2	2	7	TR	FL		1		1	14	1
380	2	1	-0	1	2	2	8	TR	FL	1	1		1	1	1
390	1	-0	2	-0	3	3	9	TR	FL	1		1		1	1
400	-0	1	1	1	4	13	20	TR	FL		1	1	1	1	1
410	-0	-0	-0	1	2	1	4	TR	FL				1	1	1
420	-0	-0	2	1	3	1	7	TR	FL			1	1	1	1
430	2	-0	-0	13	7	5	27	TR	FL	1			1	14	1
440	3	1	-0	7	8	2	21	TR	FL	1	1		1	1	1
450	3	-0	-0	6	7	3	19	TR	FL	1			1	1	1
460	2	1	-0	3	14	1	21	TR	FL	1	1		1	1	1
470	1	1	-0	1	19	2	24	TR	FL	1	1		1	1	1
480	-0	-0	-0	7	9	7	23	TR	FL				1	1	1
490	-0	-0	-0	5	8	1	14	TR	FL				1	1	1
500	4	6	-0	10	13	2	35	TR	FL	1	1		1	1	1
510	-0	-0	-0	17	10	3	30	TR	FL				1	1	1
520	2	3	-0	6	72	11	94	TR	FL	1	1		1	1	1
530	-0	-0	-0	7	25	15	47	TR	FL				1	14	1
540	1	-0	-0	7	13	1	22	TR	FL	1			1	14	1
550	-0	-0	-0	12	22	6	40	TR	FL				14	14	1
560	-0	-0	-0	7	26	7	40	TR	FL				1	1	13
570	7770	-0	-0	10	14	4	28	TR	FL				1	1	1
580	1	-0	-0	3	29	18	51	TR	FL	1			1	13	1
590	-0	-0	-0	3	16	2	21	TR	FL				1	14	1
600	-0	-0	-0	3	31	3	37	TR	FL				1	1	1
610	1	-0	-0	-0	5	-0	6	TR	FL	1				1	
620	-0	-0	-0	-0	8	3	11	TR	FL					1	1
630	-0	1	-0	5	4	4	14	TR	FL		1		13	1	1
640	-0	-0	-0	5	4	-0	9	TR	FL				1	13	

650	-0	-0	-0	5	11	-0	16	TR		FL		1	1	
660	-0	-0	-0	-0	4	3	7	TR		FL			1	1
670	-0	-0	-0	18	30	6	54	PY-1	TR 3			1	1	1
680	-0	-0	-0	7	32	4	43	TR 3				13	1	13
690	-0	-0	-0	1	7	4	12	TR 3				1	1	1
700	-0	-0	-0	-0	13	3	16	TR 3					1	1
710	3	-0	-0	9	10	3	25	TR 3			1	1	1	1
720	-0	-0	-0	-0	18	5	23	TR 3					1	1
730	-0	-0	-0	-0	3	5	8	TR 3					1	1
740	-0	-0	-0	1	5	-0	6	TR 3				1	1	
750	-0	-0	-0	1	6	3	10	TR 3				1	1	1
760	-0	-0	-0	1	7	7	15	TR 3				1	1	1
770	-0	-0	-0	2	6	5	13	TR 3				1	1	1
780	-0	-0	-0	-0	3	5	8	TR 3					1	1
790	-0	-0	-0	1	3	2	6	TR 3				1	1	1
810	-0	-0	-0	1	19	23	43	TR 3				1	1	1
820	-0	-0	-0	1	3	2	6	TR 3				1	1	1
830	-0	-0	-0	1	12	5	18	TR 3				1	1	1
840	-0	-0	-0	2	9	14	25	TR 3				1	1	1
850	-0	-0	-0	8	15	10	33	TR 3				19	19	1
860	-0	-0	-0	1	4	3	8	TR 3				1	1	1
870	-0	-0	-0	1	2	-0	3	TR 3				1	1	
880	-0	-0	-0	1	8	3	12	TR 3				1	1	1
890	-0	-0	-0	3	6	21	30	TR 3				1	1	1
900	-0	-0	-0	1	7	10	18	TR 3				1	1	1
910	-0	-0	-0	-0	2	5	7	TR 3					1	1
920	-0	-0	-0	2	1	12	15	TR 3				1	1	1
930	1	-0	-0	6	30	3	40	TR 3			13	1	1	1
940	-0	-0	-0	8	7	4	19	TR 3				1	1	1
950	-0	-0	-0	-0	4	5	9	TR 3					1	1
960	-0	-0	-0	7	3	2	12	TR 3				1	1	1
970	-0	-0	-0	24	21	12	57	TR 3				1	1	1
980	-0	-0	-0	13	20	9	42	TR 3				1	1	1

| | | |

1320	-0	-0	-0	1	9	-0	10	TR	HF						15	15	
1330	-0	-0	-0	1	17	2	20	TR	HF						15	15	15
1340	-0	-0	-0	-0	3	1	4	TR	HF							15	15
1350	-0	-0	-0	-0	9	1	10	TR	HF							15	15
1360	-0	1	-0	2	23	2	28	TR	HF				1		1	1	1
1370	-0	-0	-0	2	1	-0	3	TR	?						1	1	
1380	-0	-0	-0	6	6	-0	12	TR	?						13	1	
1390	-0	-0	-0	2	5	-0	7	TR	?						1	1	
1400	-0	-0	-0	2	30	3	35	TR			HFFL				1	1	1
1410	-0	1	-0	3	16	6	26	TR			HFFL		1		1	1	1
1420	-0	2	-0	5	28	5	40	TR			HFFL		1		1	1	1
1430	1	3	-0	21	35	1	61	TR			HFFL	1	1		1	1	1
1440	-0	1	-0	5	36	3	45	TR			HFFL		1		1	1	1
1450	-0	1	-0	7	28	2	37	TR			HFFL		13		13	1	1
1460	-0	-0	-0	3	30	9	42	TR			HFFL				1	1	1
1470	-0	-0	-0	2	19	-0	21	TR			HFFL				1	1	
1480	-0	-0	-0	4	7	-0	11	TR			HFFL				1	13	
1490	-0	-0	-0	-0	5	-0	5	TR			HFFL					1	
1500	-0	-0	-0	4	7	1	12	TR			HFFL				1	14	1
1510	-0	-0	-0	1	4	1	6	TR			HFFL				1	1	1
1520	-0	-0	-0	9	32	4	45	TR			HFFL				1	1	1
1530	3	3	-0	14	73	-0	93	TR			HFFL	1	1		1	1	
1540	6	4	-0	27	41	12	89	FL	TR			1	1		1	1	1

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DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
20	-0	-0	-0	-0	-0	1	1	PD 3									1
30	-0	-0	-0	-0	-0	1	1	PD 3									13
40	-0	-0	-0	-0	-0	1	1	PD									132
50	-0	-0	-0	-0	-0	3	3	PD 3									132
60	-0	1	-0	-0	-0	1	2	PD 3					1				1
70	-0	-0	-0	-0	-0	2	2	PD 3									1
80	-0	-0	1	-0	-0	1	2	PD 3						1			1
90	-0	-0	-0	-0	-0	-0	-0	PD 3									
100	-0	-0	-0	-0	-0	1	1	PD 3									1
110	-0	-0	-0	-0	-0	-0	-0	PD 3									
120	2	-0	-0	5	1	9	17	PD 3				1			1	1	15
130	-0	-0	-0	-0	-0	3	3	PD 3									1
140	-0	-0	-0	-0	-0	2	2	PD 3									12
150	-0	-0	1	-0	2	3	6	PD 3						1		1	1
160	-0	-0	-0	5	3	17	25	PD 3							1	1	1
170	-0	-0	-0	-0	10	-0	10	PD 3								13A	
180	-0	-0	-0	-0	8	9	17	PD 3								13	13
190	1	1	-0	2	6	34	44	PD 3				1	1		1	13	15
200	-0	1	-0	-0	-0	-0	1	PD 3					1				
210	-0	-0	-0	-0	4	2	6	PD 3								1	1
220	-0	1	1	-0	1	2	5	PD 3					1	1		1	1
230	-0	-0	-0	-0	-0	1	1	PD 3									1
240	-0	3	-0	5	8	6	22	PY 2					1		1	1	1
250	-0	3	1	6	7	-0	17	PY 2					1	1	1	1	
260	-0	-0	-0	2	8	-0	10	PY 2							1	13	
270	-0	-0	-0	10	9	-0	19	PD 3	PY						1	1	
280	-0	-0	-0	3	6	-0	9	PD 3	PY						1	1	
290	-0	-0	-0	3	4	-0	7	PD 3	PY						13	1	
300	-0	1	-0	3	3	-0	7	PD 3	PY				1		1	13	

310	-0	-0	-0	2	-0	1	3	PD 3	PY					1		13	
320	1	1	-0	8	2	3	15	PD 3	PY	13	1			1	1	1	
330	2	3	-0	2	3	2	12	PD 3	PY	1	1			1	1	1	
340	-0	-0	-0	-0	6	1	7	AT 2	PD 3						1	1	
350	-0	-0	-0	3	13	1	17	AT 2						1	1	1	
360	-0	1	-0	6	20	3	30	AT 2			1			1	1	1	
370	-0	-0	-0	4	4	-0	8	AT 2						1	1		
380	-0	-0	-0	3	6	-0	9	AT 2						1	1		
390	-0	-0	-0	-0	1	-0	1	AT 2							1		
400	1	-0	-0	3	4	4	12	AT 2		1				1	1	1	
410	-0	-0	-0	-0	1	2	3	AT 2							1	1	
416	-0	-0	-0	2	-0	1	3	AT 2						1		1	

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DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
70	-0	-0	-0	7	3	2	12	TR	3						1	1	1
80	-0	-0	-0	2	6	4	12	TR	3						1	1	1
90	-0	-0	-0	3	15	22	40	TR	3						1	1	1
100	-0	-0	-0	3	10	10	23	TR	3						1	1	1
110	-0	-0	-0	2	11	17	30	TR	3						1	1	1
120	-0	-0	1	5	12	17	35	TR	3					1	13	1	1
130	-0	-0	-0	1	7	4	12	TR	3						1	13	1
140	-0	-0	-0	6	7	4	17	TR	3						1	1	1
150	-0	-0	-0	3	10	3	16	TR	3						1	1	1
160	-0	-0	-0	7	3	5	15	TR	3						1	1	1
170	-0	-0	-0	5	4	6	15	TR	3						1	1	1
180	-0	-0	-0	3	5	10	18	TR	3						1	1	1
190	-0	-0	-0	5	2	1	8	TR	3						1	1	13
200	-0	-0	-0	2	1	7	10	TR	3						1	1	1
210	-0	-0	-0	1	1	6	8	TR	3						1	1	1
220	-0	-0	-0	3	2	4	9	TR	3						1	1	1
230	-0	-0	-0	2	2	9	13	TR	3						1	1	1
240	-0	-0	-0	-0	3	5	8	TR	3							1	1
250	-0	-0	-0	1	3	2	6	TR	3						1	1	1
260	-0	-0	-0	-0	2	3	5	TR	3							1	1
270	-0	-0	-0	1	4	4	9	TR	3						1	1	1
280	-0	-0	-0	1	9	7	17	TR	3						1	1	1
290	-0	-0	-0	2	2	7	11	TR	3						1	1	1
300	-0	-0	-0	-0	1	2	3	TR	3							1	1
310	-0	-0	-0	7	4	5	16	TR	2						1	1	1
320	-0	-0	-0	3	9	1	13	TR	2						1	1	1
330	-0	-0	-0	-0	2	5	7	TR	2							1	1
340	-0	-0	-0	1	5	9	14	TR	2						1	1	1
350	-0	-0	-0	4	4	6	14	TR	2						1	1	1

| | | |

690	-0	-0	-0	1	-0	5	6	TR 2	TR 1	S		1		1
700	-0	-0	-0	-0	1	4	5	TR 2	TR 1	S			1	1
710	-0	-0	-0	4	11	4	19	TR 2	TR 1	S		1	13	1
720	-0	-0	-0	5	1	5	11	TR 2	TR 1	S		1	1	1
730	-0	-0	-0	2	2	1	5	TR 2	TR 1	S		1	1	1
740	-0	-0	-0	2	-0	-0	2	TR 2	TR 1	S		1		
750	-0	-0	-0	3	-0	2	5	TR 2	TR 1	S		1		1
760	-0	-0	-0	4	-0	5	9	TR 2	TR 1	S		1		1
770	-0	-0	-0	4	-0	3	7	TR 2	TR 1	S		1		1
780	-0	-0	-0	2	3	11	16	TR 2	TR 1	S		1	1	1
790	-0	-0	-0	1	4	7	12	TR 2	TR 1	S		1	1	1
800	-0	-0	-0	-0	1	4	5	TR 2	TR 1	S			1	1
810	-0	-0	-0	1	9	6	16	TR 2		S		1	1	1
820	-0	-0	-0	4	8	10	22	TR 2		S		1	1	1
830	-0	-0	-0	4	8	3	15	TR 2		S		1	1	1
840	-0	-0	-0	3	2	6	11	TR 2		S		1	1	1
850	-0	-0	-0	-0	4	2	6	TR 2		S			123	1
860	-0	-0	-0	1	7	2	10	TR 2		S		1	1	1
870	-0	-0	-0	4	5	2	11	TR 2		S		1	1	1
880	-0	-0	-0	4	2	2	8	TR 2		S		1	1	1
890	-0	-0	-0	6	5	6	17	TR 2		S		1	1	1
900	-0	-0	-0	6	7	4	17	TR 2		S		1	1	1
910	-0	1	-0	9	15	2	27	TR 2		S	1	1	1	1
920	-0	-0	-0	4	5	5	14	TR 1		S	HF	12	1	123
930	-0	-0	-0	6	12	26	44	TR 1		S	HF	1	13	1
940	-0	-0	-0	3	7	38	48	TR 1		S	HF	1	13	13
950	-0	-0	-0	1	9	6	16	TR 1		S	HF	1	12	13
960	-0	-0	-0	5	3	2	10	TR 1		S	HF	13	1	1
970	-0	-0	-0	-0	-0	3	3	TR 1		S	HF			13
980	-0	-0	-0	-0	1	1	2	TR 1		S	HF		13	13
990	-0	-0	-0	1	3	5	9	TR 1		S	HF	13	13	13
1000	-0	-0	-0	2	-0	2	4	TR 1		S	HF	1		1
1010	-0	-0	-0	-0	-0	2	2	TR 1		S	HF			13

1020	-0	-0	-0	5	-0	4	9	TR 1		S HF		13	13
1030	-0	-0	-0	2	-0	5	7	TR 1		S HF		1	1
1040	-0	-0	-0	9	3	5	17	TR 1		S HF		1 1	1
1050	-0	-0	-0	9	3	2	14	TR 1		S HF		13 1	1
1060	-0	-0	-0	-0	-0	11	11	TR 1		S HF			1
1070	-0	-0	-0	2	1	11	14	TR 1		S HF		1 1	1
1080	-0	-0	-0	-0	3	10	13	TR 1		S HF		1	1
1090	-0	-0	-0	6	1	13	20	TR 1		S HF		1 1	1
1100	-0	-0	-0	7	2	6	15	TR 1		S HF		1 1	1
1110	-0	-0	-0	7	4	3	14	TR 1		S HF		13 1	1
1120	-0	-0	-0	4	14	4	22	TR 1		S HF		13 13	1
1130	-0	-0	-0	3	2	6	15	TR 1		S HF		1 1	1
1140	-0	-0	-0	2	4	8	14	TR 1		S HF		1 1	1
1150	-0	-0	-0	10	-0	10	20	TR 1		S HF		1	1
1160	-0	-0	-0	1	-0	10	11	TR 1		S HF		1	1
1170	-0	-0	-0	3	2	6	11	TR 1		S HF		1 1	1
1180	-0	-0	-0	1	4	4	9	TR 1		S HF		1 1	1
1190	-0	-0	-0	13	8	7	28	TR 1		S HF		1 1	1
1200	-0	-0	-0	8	5	13	26	TR 1	HF			1 1	1
1210	-0	-0	-0	8	11	16	35	TR 1	HF			1 1	1
1220	-0	-0	-0	9	4	10	23	TR 1	HF			1 1	1
1230	-0	-0	-0	9	4	7	20	TR 1	HF			1 1	1
1240	-0	-0	-0	5	5	7	17	TR 1	HF			1 1	1
1250	-0	-0	-0	4	8	4	16	TR 1	HF			13 13	13
1260	-0	-0	-0	2	7	13	22	TR 1	HF			1 13	13
1270	-0	-0	-0	4	5	6	15	HF	TR 1			13 13	13
1280	-0	-0	-0	13	14	12	42	HF	TR 1			1 1	13
1290	-0	-0	-0	25	37	23	85	HF	TR 1			1 13	13
1300	-0	-0	-0	12	24	15	51	HF	TR 1			12 123	12
1310	-0	-0	-0	15	39	4	58	HF	TR 1			1 13	1
1321	-0	-0	-0	11	25	24	60	HF	TR 1			1 13	13

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DEPTH	OPEN FRACTURES			CLOSED FRACTURES			TOTAL	ROCK TYPE				OPEN FILLING			CLOSED FILLING		
	0-30	30-60	60-90	0-30	30-60	60-90		RT	RT	M	INCL	0-30	30-60	60-90	0-30	30-60	60-90
40	1	1	-0	8	31	35	76	TR 3				1	1		13	13	13
50	-0	-0	-0	7	23	7	42	TR 3							13	13	13
60	-0	-0	-0	14	104	5	123	TR 3							123	1	1
70	-0	-0	-0	19	70	16	105	TR 3							132	123	1
80	-0	-0	-0	11	12	2	25	TR 3							132	1	1
90	1	-0	-0	19	23	11	54	TR 3	TR 2			1			13	13	1
100	-0	-0	-0	21	53	17	90	TR 2		S					13	12	13
110	-0	-0	-0	10	37	21	68	TR 2		S					1	13	13
120	-0	-0	-0	4	13	2	19	TR 3		S					12	123	1
130	-0	-0	-0	3	6	-0	9	TR 2		S					123	13	
140	-0	-0	-0	-0	6	-0	6	TR 2		S						24	
150	-0	-0	-0	1	-0	-0	1	TR 2		S					3		
160	-0	-0	-0	4	-0	-0	4	TR 2		S					32		
170	-0	-0	-0	1	2	1	4	TR 2		S					3	13	2
180	-0	-0	-0	1	2	2	5	TR 2		S					2	2	3
190	1	-0	-0	-0	-0	7	8	TR 2		S		1					32
200	1	-0	-0	2	1	1	5	TR 1		S	GRHF	1			2	2	3
210	-0	-0	-0	37	12	-0	49	TR 1		S	GRHF				2	2	
220	-0	-0	-0	19	20	-0	39	TR 1		S	GRHF				2	2	
230	-0	-0	-0	15	17	-0	32	TR 1		S	GRHF				2	2	
240	-0	-0	-0	11	13	-0	24	TR 1		S	GRHF				24	2	
250	-0	-0	-0	3	18	1	22	TR 1		S	GRHF				2	21	1
260	-0	-0	-0	12	17	1	30	TR 1			GRHF				12	12	12
270	-0	-0	-0	8	18	3	29	TR 1			GRHF				12	12	12
280	-0	-0	-0	3	13	-0	26	TR 1			GRHF				12	12	12
290	-0	-0	-0	12	12	4	28	TR 1			GRHF				13	1	1
300	-0	-0	-0	6	17	1	24	TR 1			GRHF				13	1	1
310	-0	-0	-0	3	17	2	22	TR 1			GRHF				12	123	123
320	-0	-0	-0	2	32	3	37	TR 1			GRHF				12	12	12

330	-0	-0	-0	6	17	1	24	TR 1	GRHF	12	12	12
340	-0	-0	-0	6	18	1	25	TR 1	GRHF	12	12	12
350	-0	-0	-0	8	31	4	43	TR 1	GRHF	12	12	12
360	-0	-0	-0	8	23	3	34	TR 1	GRHF	1	1	1
370	-0	-0	-0	6	26	1	33	TR 1	GRHF	1	1	1
380	-0	-0	-0	2	11	4	17	TR 1	GRHF	13	1	1
390	-0	-0	-0	12	17	2	31	TR 1	GRHF	1	1	1
400	-0	-0	-0	2	12	3	17	TR 1	GRHF	1	1	1
410	-0	-0	-0	2	3	2	7	TR 1	GRHF	1	1	13
420	-0	-0	-0	3	14	2	19	TR 1	GRHF	1	13	1
430	-0	-0	-0	6	11	3	20	TR 1	GRHF	12	13	1
440	-0	-0	-0	-0	15	1	16	TR 1	GRHF		12	1
450	-0	-0	-0	3	24	3	30	TR 1	GRHF	1	13	1
460	-0	-0	-0	2	20	5	27	TR 1	GRHF	1	13	1
470	-0	-0	-0	6	25	5	36	TR 1	GRHF	12	12	123
480	-0	-0	-0	10	35	5	50	TR 1	GRHF	124	12	12
490	-0	-0	-0	8	28	3	39	TR 1	GRHF	12	12	12
510	-0	-0	-0	3	27	1	31	TR 1	GRHF	124	12	12
520	-0	-0	-0	12	25	3	40	TR 1	GRHF	12	124	12
530	-0	-0	-0	4	26	3	33	TR 1	GRHF	12	12	12
550	-0	-0	-0	3	28	8	40	TR 1	GRHF	12	12	12
560	-0	-0	-0	4	32	7	43	TR 1	GRHF	1	1	1
580	-0	-0	-0	-0	5	2	7	TR 1	GRHF		1	1
590	-0	-0	-0	12	4	3	19	TR 1	GRHF	1	1	1
595	-0	-0	-0	4	20	1	25	TR 1	GRHF	1	1	1

PART 2

DRILL HOLE FRACTURES ROCK TYPE = S

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	4	IN3267A	
	6	IN3267A	

867953

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630	4	IN32727A
650	7	IN32727A
640	7	IN32727A
690	11	IN32727A
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1070	63	IC32730
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1110	34	IC32730
1120	39	IC32730
1130	38	IC32730
1140	11	IC32730
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730	5	A3-5
740	2	A3-5
750	5	A3-5
760	9	A3-5
770	7	A3-5
780	16	A3-5
790	12	A3-5

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95 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(.084 .194)(.186 .290)(.210 .385)(.316 .477)(.425 .568)(.535 .658)(.648 .746)(.763 .832)(.880 .917)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 297

LEAST SQUARES FIT (LINEAR) Y = A(* A1)

A(= 667.36 +- 25.34

A1 = -2.71 +- .87

STANDARD ERROR = 299.84

CORRELATION COEFFICIENT R = -.17812

DRILL HOLE FRACTURES ROCK TYPE = TR

DEPTH	FRACTURES	ID
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80	20	A4-9
90	24	A4-9
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110	14	A4-9
120	32	A4-9
130	61	A4-9
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150	22	A4-9
160	27	A4-9
170	39	A4-9
180	75	A4-9
190	39	A4-9
200	32	A4-9
210	7	A4-9
220	28	A4-9
230	23	A4-9
240	12	A4-9
250	45	A4-9
260	62	A4-9
270	27	A4-9
280	25	A4-9
290	5	CN-3
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310	47	CN-3
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330	18	CN-3
340	10	CN-3
350	9	CN-3
360	4	CN-3
370	3	CN-3
380	5	CN-3
390	1	CN-3
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410	12	CN-3
420	6	CN-3
430	6	CN-3
440	28	CN-3
450	13	CN-3
460	32	CN-3
470	14	CN-3
480	22	A4-6
490	10	A4-6
500	19	A4-6
510	7	A4-6
520	9	A4-6
530	15	A4-6
540	8	A4-6
550	14	A4-6
560	7	A4-6
570	16	A4-6
580	9	A4-6
590	8	A4-6
600	14	A4-6
610	8	A4-6

10	20	A4-6
40	76	A4-1
50	42	A4-1
60	123	A4-1
70	105	A4-1
80	25	A4-1
90	54	A4-1
100	90	A4-1
110	68	A4-1
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140	6	A4-1
150	1	A4-1
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470	36	A4-1
480	50	A4-1
490	39	A4-1
500	31	A4-1
510	40	A4-1
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550	7	A4-1
560	19	A4-1
565	25	A4-1
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180	38	IC32718
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200	81	IC32718
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220	15	IC32718
230	39	IC32718
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270	12	IC32718

632155

270	12	IC32718
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290	19	IC32718
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380	12	IC32718
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400	15	IC32718
410	-0	IC32718
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430	-0	IC32718
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450	11	IC32718
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670	2	IC32718
680	1	IC32718
690	1	IC32718
700	3	IC32718
710	27	IC32718
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10	117	A4-8
20	83	A4-8
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40	74	A4-8
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110	24	A4-8
120	25	A4-8
130	33	A4-8
140	46	A4-8
150	18	A4-8
160	12	A4-8
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180	20	A4-8
190	17	A4-8
200	36	A4-8
210	18	A4-8
220	18	A4-8
230	52	A4-8

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560	4	CN-9
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580	3	CN-9
590	15	CN-9
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710	24	CN-9
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740	23	CN-9
750	8	CN-9
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[illegible]	1	IN32727A
[illegible]	2	IN32727A
[illegible]	4	IN32727A
[illegible]	5	IN32727A
[illegible]	2	IN32727A
[illegible]	1	IN32727A
[illegible]	8	IN32727A
[illegible]	1	IN32727A
[illegible]	3	IN32727A
[illegible]	6	IN32727A
[illegible]	2	IN32727A
[illegible]	3	IN32727A
[illegible]	0	IN32727A
[illegible]	6	IN32727A
[illegible]	23	IN32727A

442	14	IN32727A
451	11	IN32727A
459	6	IN32727A
470	47	IN32727A
480	54	IN32727A
490	27	IN32727A
500	11	IN32727A
510	11	IN32727A
520	8	IN32727A
530	22	IN32727A
543	17	IN32727A
551	33	IN32727A
582	7	IN32727A
570	9	IN32727A
581	10	IN32727A
590	9	IN32727A
601	10	IN32727A
610	19	IN32727A
629	14	IN32727A
639	12	IN32727A
651	14	IN32727A
661	18	IN32727A
671	20	IN32727A
677	5	IN32727A
682	7	IN32727A
693	4	IN32727A
710	14	IN32727A
71	10	IN32727A
73	2	IN32727A
74	2	IN32727A
743	4	IN32727A
75	5	IN32727A
760	5	IN32727A
77	9	IN32727A
785	5	IN32727A
795	5	IN32727A
803	4	IN32727A
815	6	IN32727A
82	2	IN32727A
83	4	IN32727A
847	7	IN32727A
855	7	IN32727A
866	11	IN32727A
877	15	IN32727A
892	15	IN32727A
907	14	IN32727A
91	2	IC32730
92	6	IC32730
93	8	IC32730
94	3	IC32730
95	4	IC32730
96	7	IC32730
97	6	IC32730
100	8	IC32730
110	7	IC32730
120	8	IC32730
130	5	IC32730
140	7	IC32730
150	6	IC32730
160	7	IC32730
170	10	IC32730
180	2	IC32730
190	6	IC32730
200	4	IC32730
207	7	IC32730
220	10	IC32730

230	19	IC32730
240	15	IC32730
250	13	IC32730
260	6	IC32730
270	8	IC32730
280	7	IC32730
290	7	IC32730
300	14	IC32730
310	12	IC32730
320	9	IC32730
330	5	IC32730
340	7	IC32730
350	5	IC32730
360	6	IC32730
370	3	IC32730
380	1	IC32730
390	2	IC32730
400	4	IC32730
410	4	IC32730
420	7	IC32730
430	8	IC32730
440	1	IC32730
450	1	IC32730
460	7	IC32730
470	27	IC32730
480	7	IC32730
490	4	IC32730
500	6	IC32730
510	2	IC32730
520	5	IC32730
530	20	IC32730
540	8	IC32730
550	4	IC32730
560	2	IC32730
570	5	IC32730
580	10	IC32730
590	7	IC32730
600	2	IC32730
610	-0	IC32730
620	-0	IC32730
630	-0	IC32730
640	-0	IC32730
650	-0	IC32730
660	2	IC32730
670	3	IC32730
680	5	IC32730
690	15	IC32730
700	13	IC32730
710	17	IC32730
720	15	IC32730
730	15	IC32730
740	3	IC32730
750	4	IC32730
760	4	IC32730
770	22	IC32730
780	18	IC32730
790	10	IC32730
800	10	IC32730
810	8	IC32730
820	10	IC32730
830	4	IC32730
840	10	IC32730
850	10	IC32730
860	12	IC32730
870	13	IC32730

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910	5	IC32730
920	13	IC32730
930	30	IC32730
940	13	IC32730
950	25	IC32730
960	12	IC32730
970	14	IC32730
980	3	IC32730
990	3	IC32730
1000	12	IC32730
1010	3	IC32730
1020	14	IC32730
1030	14	IC32730
1040	16	IC32730
1050	16	IC32730
1060	39	IC32730
1070	63	IC32730
1080	38	IC32730
1090	10	IC32730
1100	29	IC32730
1110	34	IC32730
1120	39	IC32730
1130	33	IC32730
1140	11	IC32730
10	12	A3-5
20	12	A3-5
30	40	A3-5
40	23	A3-5
110	30	A3-5
120	35	A3-5
130	14	A3-5
140	17	A3-5
150	15	A3-5
160	15	A3-5
170	15	A3-5
180	18	A3-5
190	6	A3-5
200	10	A3-5
210	8	A3-5
220	9	A3-5
230	13	A3-5
240	8	A3-5
250	5	A3-5
260	5	A3-5
270	9	A3-5
280	17	A3-5
290	11	A3-5
300	3	A3-5
310	16	A3-5
320	13	A3-5
330	7	A3-5
340	14	A3-5
350	14	A3-5
360	7	A3-5
370	12	A3-5
380	11	A3-5
390	11	A3-5
400	19	A3-5
410	25	A3-5
420	16	A3-5
430	4	A3-5
440	7	A3-5
450	7	A3-5
460	4	A3-5
470	8	A3-5
480	7	A3-5

490	4	A3-5	
550	5	A3-5	
511	5	A3-5	
525	4	A3-5	
520	5	A3-5	
540	8	A3-5	
554	7	A3-5	
570	4	A3-5	
550	4	A3-5	
590	2	A3-5	
615	4	A3-5	
610	1	A3-5	
620	1	A3-5	
610	3	A3-5	
660	5	A3-5	
650	6	A3-5	
665	5	A3-5	
670	6	A3-5	
700	7	A3-5	
710	6	A3-5	
720	5	A3-5	
730	10	A3-5	
740	11	A3-5	
750	5	A3-5	
760	7	A3-5	
770	15	A3-5	
780	14	A3-5	
790	5	A3-5	
800	14	A3-5	
810	22	A3-5	
820	17	A3-5	
830	11	A3-5	
840	6	A3-5	
850	13	A3-5	
860	11	A3-5	
870	6	A3-5	
880	17	A3-5	
890	17	A3-5	
900	27	A3-5	
910	14	A3-5	
920	46	A3-5	
930	43	A3-5	
940	16	A3-5	
950	15	A3-5	
960	3	A3-5	
970	2	A3-5	
980	9	A3-5	
990	4	A3-5	
1000	2	A3-5	
1010	4	A3-5	
1020	7	A3-5	
1030	17	A3-5	
1040	14	A3-5	
1050	11	A3-5	
1060	14	A3-5	
1070	13	A3-5	
1080	25	A3-5	
1090	15	A3-5	
1100	14	A3-5	
1110	22	A3-5	
1120	15	A3-5	
1130	14	A3-5	
1140			

20	A3-5		
11	A3-5		
11	A3-5		
9	A3-5		
24	A3-5		
26	A3-5		
35	A3-5		
24	A3-5		
20	A3-5		
17	A3-5		
16	A3-5		
22	A3-5		
4	N4-11		
1	N5-11		
4	W8-11		
2	W9-11		
1	N4-11		
1	N5-11		
1	N4-11		
1	N4-11		
5	N5-11		
3	N5-11		
4	N7-11		
1	N9-11		
6	N4-11		
8	E1-11		
7	W1-11		
6	J1-11		
7	J1-11		
14	N4-11		
26	N4-11		
11	N5-11		
33	N4-11		
31	N4-11		
14	E4-11		
11	E4-11		
5	J1-11		
12	N9-11		
11	J4-11		
17	J4-11		
13	J5-11		
17	N1-11		
4	N1-11		
14	N1-11		
3	E7-11		
11	N4-11		
7	N4-11		
8	N5-11		
9	J4-11		
20	N11-11		
4	N4-11		
7	N4-11		
27	N5-11		
21	N5-11		
19	N5-11		
21	N4-11		
24	N4-11		
23	N4-11		
14	N4-11		
35	N5-11		
36	N4-11		
94	N4-11		
47	N4-11		
22	N4-11		
40	N4-11		
46	N4-11		

1151	
1161	
1171	
1191	
1194	
1206	
1214	
1224	
1234	
1247	
1261	
1266	
39	
41	
50	
70	
88	
95	
111	
113	
128	
135	
142	
150	
172	
181	
204	
214	
220	
230	
254	
307	
327	
341	
352	
361	
374	
390	
395	
407	
418	
423	
432	
441	
453	
466	
478	
488	
498	
506	
514	
523	
531	
549	
558	
566	

692173

570	26	NM-11
580	51	NM-11
590	21	NM-11
600	37	NM-11
610	6	NM-11
620	11	NM-11
630	14	NM-11
640	9	NM-11
650	15	NM-11
660	7	NM-11
680	43	NM-11
690	12	NM-11
700	16	NM-11
710	25	NM-11
720	23	NM-11
730	8	NM-11
740	6	NM-11
750	10	NM-11
760	15	NM-11
770	13	NM-11
780	8	NM-11
790	5	NM-11
810	43	NM-11
820	6	NM-11
830	18	NM-11
840	25	NM-11
850	33	NM-11
860	8	NM-11
870	3	NM-11
880	12	NM-11
890	30	NM-11
900	16	NM-11
910	7	NM-11
920	15	NM-11
930	40	NM-11
940	19	NM-11
950	9	NM-11
960	12	NM-11
970	57	NM-11
980	42	NM-11
990	101	NM-11
1000	33	NM-11
1010	44	NM-11
1020	69	NM-11
1030	58	NM-11
1040	33	NM-11
1050	32	NM-11
1060	8	NM-11
1070	8	NM-11
1080	17	NM-11
1090	25	NM-11
1100	36	NM-11
1110	56	NM-11
1120	12	NM-11
1130	33	NM-11
1140	35	NM-11
1150	40	NM-11
1160	17	NM-11
1170	58	NM-11
1180	54	NM-11
1190	21	NM-11
1200	63	NM-11
1210	75	NM-11
1220	52	NM-11
1230	24	NM-11
1250	15	NM-11

1260	22	NM-11
1270	31	NM-11
1280	58	NM-11
1290	19	NM-11
1300	16	NM-11
1310	17	NM-11
1320	10	NM-11
1330	20	NM-11
1340	4	NM-11
1350	10	NM-11
1360	28	NM-11
1370	3	NM-11
1380	12	NM-11
1390	7	NM-11
1400	35	NM-11
1410	26	NM-11
1420	40	NM-11
1430	61	NM-11
1440	45	NM-11
1450	37	NM-11
1460	42	NM-11
1470	21	NM-11
1480	11	NM-11
1490	5	NM-11
1500	12	NM-11
1510	6	NM-11
1520	45	NM-11
1530	93	NM-11

90 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(.143 .157)(.144 .255)(.247 .352)(.350 .447)(.455 .542)(.562 .636)(.669 .728)(.778 .820)(.888 .910)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 413

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X

A0 = 509.78 +- 17.24

A1 = .57 +- .62

STANDARD ERROR = 346.87

CORRELATION COEFFICIENT R = -.02092

1[illegible]	22	NM=11
1[illegible]	31	NM=11
1[illegible]	58	NM=11
1[illegible]	19	NM=11
1[illegible]	16	NM=11
1311	17	NM=11
1[illegible]	19	NM=11
1[illegible]	20	NM=11
1[illegible]	4	NM=11
1[illegible]	10	NM=11
1[illegible]	28	NM=11
1[illegible]	3	NM=11
1[illegible]	12	NM=11
1[illegible]	7	NM=11
1[illegible]	35	NM=11
1[illegible]	26	NM=11
1[illegible]	40	NM=11
1[illegible]	61	NM=11
1[illegible]	45	NM=11
1[illegible]	37	NM=11
1[illegible]	42	NM=11
1[illegible]	21	NM=11
1[illegible]	11	NM=11
1[illegible]	5	NM=11
1[illegible]	12	NM=11
1[illegible]	5	NM=11
1[illegible]	4[illegible]	NM=11
1[illegible]	94	NM=11

90 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(.047 .157)(.144 .255)(.247 .352)(.350 .447)(.455 .542)(.562 .636)(.669 .728)(.778 .820)(.888 .910)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 813

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X

A0 = 509.78 +- 17.24

A1 = .57 +- .62

STANDARD ERROR = 346.87

CORRELATION COEFFICIENT R = -.02092

DRILL HOLE FRACTURES ROCK TYPE = PD

DEPTH	FRACTURES	TD
270	41	CN-3
280	11	CN-3
290	14	CN-3
300	11	CN-3
320	12	CN-3
20	1	A1-1
30	1	A1-1
40	1	A1-1
50	3	A1-1
60	2	A1-1
70	2	A1-1
80	2	A1-1
90	0	A1-1
100	1	A1-1
110	0	A1-1
120	17	A1-1
130	3	A1-1
140	2	A1-1
150	6	A1-1
160	23	A1-1
170	16	A1-1
180	17	A1-1
190	44	A1-1
200	1	A1-1
210	6	A1-1
220	5	A1-1
230	1	A1-1
240	19	A1-1
250	9	A1-1
260	7	A1-1
270	7	A1-1
280	3	A1-1
290	15	A1-1
300	12	A1-1
40	8	CN-2
50	42	CN-2
60	23	CN-2
70	22	CN-2
80	55	CN-2
90	42	CN-2
100	19	CN-2
110	43	CN-2
120	30	CN-2
130	13	CN-2
140	6	CN-2
150	11	CN-2
160	9	CN-2
170	7	CN-2
180	19	CN-2
190	14	CN-2
200	1	CN-2
210	8	CN-2
220	9	CN-2
230	6	CN-2
240	5	CN-2
250	1	CN-2
260	5	CN-2
270	7	CN-2
280	5	CN-2

293	3	CN=2
304	4	CN=2
310	25	CN=2
321	12	CN=2
331	7	CN=2
338	7	CN=2
350	6	CN=2

90 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(-.107 .298)(-.005 .380)(.102 .475)(.213 .559)(.329 .639)(.451 .716)(.578 .791)(.712 .863)(.852 .933)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 60

LEAST SQUARES FIT (LINEAR) Y = A0 + A1,X

A0 = 201.42 +- 16.31

A1 = -.95 +- .95

STANDARD ERROR = 95.76

CORRELATION COEFFICIENT R = -.15689

DRILL HOLE FRACTURES ROCK TYPE = HF

DEPTH	FRACTURES	ID
336	9	CN-3
340	8	CN-3
350	18	CN-3
360	6	CN-3
370	15	CN-3
380	28	CN-3
390	30	CN-3
400	16	CN-3
410	23	CN-3
420	19	CN-3
430	7	CN-3
440	4	CN-3
450	8	CN-3
460	22	CN-3
470	39	A4-6
480	18	A4-6
490	30	A4-6
500	26	A4-6
510	22	A4-6
520	7	A4-6
530	3	A4-6
540	12	A4-6
550	10	A4-6
560	17	A4-6
570	39	A4-6
580	14	A4-6
590	15	A4-6
600	33	A4-6
610	42	A4-6
620	28	A4-6
630	46	A4-6
640	33	A4-6
650	4	CN-2
660	7	CN-2
670	6	CN-2
680	9	CN-2
690	4	CN-2
700	10	CN-2
710	4	CN-2
720	3	CN-2
730	6	CN-2
740	4	CN-2
750	3	CN-2
760	4	CN-2
770	4	CN-2
780	5	CN-2
790	7	CN-2
800	7	CN-2
810	18	CN-2
820	18	CN-2
830	5	CN-2
840	3	CN-2
850	4	CN-2
1270	15	A3-5
1280	42	A3-5
1290	85	A3-5
1300	51	A3-5
1310	58	A3-5
1321	60	A3-5

99 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(-.119 .310)(-.017 .399)(.089 .485)(.201 .567)(.318 .646)(.441 .723)(.570 .796)(.706 .865)(.849 .934)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 59

LEAST SQUARES FIT (LINEAR) Y = A0 + A1*X
A0 = 333.16 +- 46.81
A1 = 9.46 +- 1.87
STANDARD ERROR = 249.18

CORRELATION COEFFICIENT R = .55419

[illegible] HOLE FRACTURES ROCK TYPE = OIL

DEPTH	FRACTURES	TD
22[illegible]	17	CM-9
23[illegible]	5	CM-9
24[illegible]	10	CM-9
25[illegible]	3	CM-9
26[illegible]	7	CM-9
27[illegible]	8	CM-9
28[illegible]	12	CM-9
29[illegible]	8	CM-9
30[illegible]	5	CM-9
31[illegible]	24	CM-9
32[illegible]	19	CM-9
33[illegible]	11	CM-9
34[illegible]	3	CM-9
35[illegible]	4	CM-9
36[illegible]	3	CM-9
37[illegible]	5	CM-9
38[illegible]	13	CM-9
39[illegible]	6	CM-9
40[illegible]	14	CM-9
41[illegible]	10	CM-9
42[illegible]	4	CM-9
43[illegible]	12	CM-9
44[illegible]	6	CM-9
45[illegible]	11	CM-9
46[illegible]	6	CM-9

95 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(-.245 .423)(-.147 .503)(-.041 .579)(.073 .649)(.196 .716)(.330 .779)(.475 .839)(.634 .896)(.808 .949)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 25

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X
A0 = 353.29 +- 29.86
A1 = -1.46 +- 2.85
STANDARD ERROR = 74.75

CORRELATION COEFFICIENT R = -.10665

ILL HOLE FRACTURES ROCK TYPE = AN

DEPTH	FRACTURES	ID
88	2	CN-9
95	9	CN-9
106	14	CN-9
110	54	CN-9
120	28	CN-9
130	50	CN-9

90 PERCENT CONFIDENCE LIMITS FOR N DATA POINTS FOR R = .1 THROUGH .9 (.05 .14)

(-.691 .782)(-.633 .819)(-.565 .851)(-.482 .879)(-.340 .905)(-.251 .928)(-.082 .949)(.148 .967)(.480 .984)

LEAST SQUARES FIT TO AN ORTHOGONAL POLYNOMIAL LSQRPY SUBROUTINE

NUMBER OF DATA POINTS = 6

LEAST SQUARES FIT (LINEAR) Y = A0 + A1 X

A0 = 86.42 +- 7.94

A1 = .71 +- .24

STANDARD ERROR = 11.76

CORRELATION COEFFICIENT R = .82689

PART 3

DEPTH IN FEET
80.
160.
240.
320.
400.
480.
560.
640.
720.
800.
-20.
0
20.
40.
60.
80.
100.
120.
140.

FRACTURES CN-7
DEPTH IN FEET X10 3
0
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
-20.
0
100.
120.
140.
FRACTURES

FRACTURES NY-7
DEPTH IN FEET X10 3
-.80
-.40
.00
.40
.80
1.20
1.60
2.00
2.40
2.80
3.20
0
20.
40.
60.
80.
100.
120.
140.
160.
NUMBER OF FRACTURES

DRILL HOLE FRACTURES NM-11
DEPTH IN FEET * X10 3
1.80
1.60
1.40
1.20
1.00
.80
.60
.40
.20
0
-.20
-20.
0
20.
40.
60.
80.
100.
120.
140.
NUMBER OF FRACTURES

DEPTH IN FEET
0
80.
160.
240.
320.
400.
480.
560.
640.
720.
-20.
0
20.
40.
60.
80.
100.
120.
140.
NUMBER OF FRACTURES

DEPTH IN FEET
50.
60.
70.
80.
90.
100.
110.
120.
130.
140.
150.
-20.
0
20.
40.
60.
80.
100.
120.
140.

DRILL HOLE FRACTURES A3-5
DEPTH IN FEET X10 3
1.80
1.60
1.40
1.20
1.00
.80
.60
.40
.20
0
-.20
-20.
0
20.
40.
60.
80.
100.
120.
140.
NUMBER OF FRACTURES

DEPTH IN FEET
-80.
0
80.
160.
240.
320.
400.
480.
560.
640.
0
20.
40.
60.
80.
100.
120.
140.
160.

DEPTH IN FEET
60.
70.
75.
80.
85.
90.
95.
100.
105.
-20.
0
20.
60.
80.
100.
120.
140.
NUMBER OF FRACTURES

FRACTURES A1-1
DEPTH IN FEET
0
50.
100.
150.
200.
250.
300.
350.
400.
450.
500.
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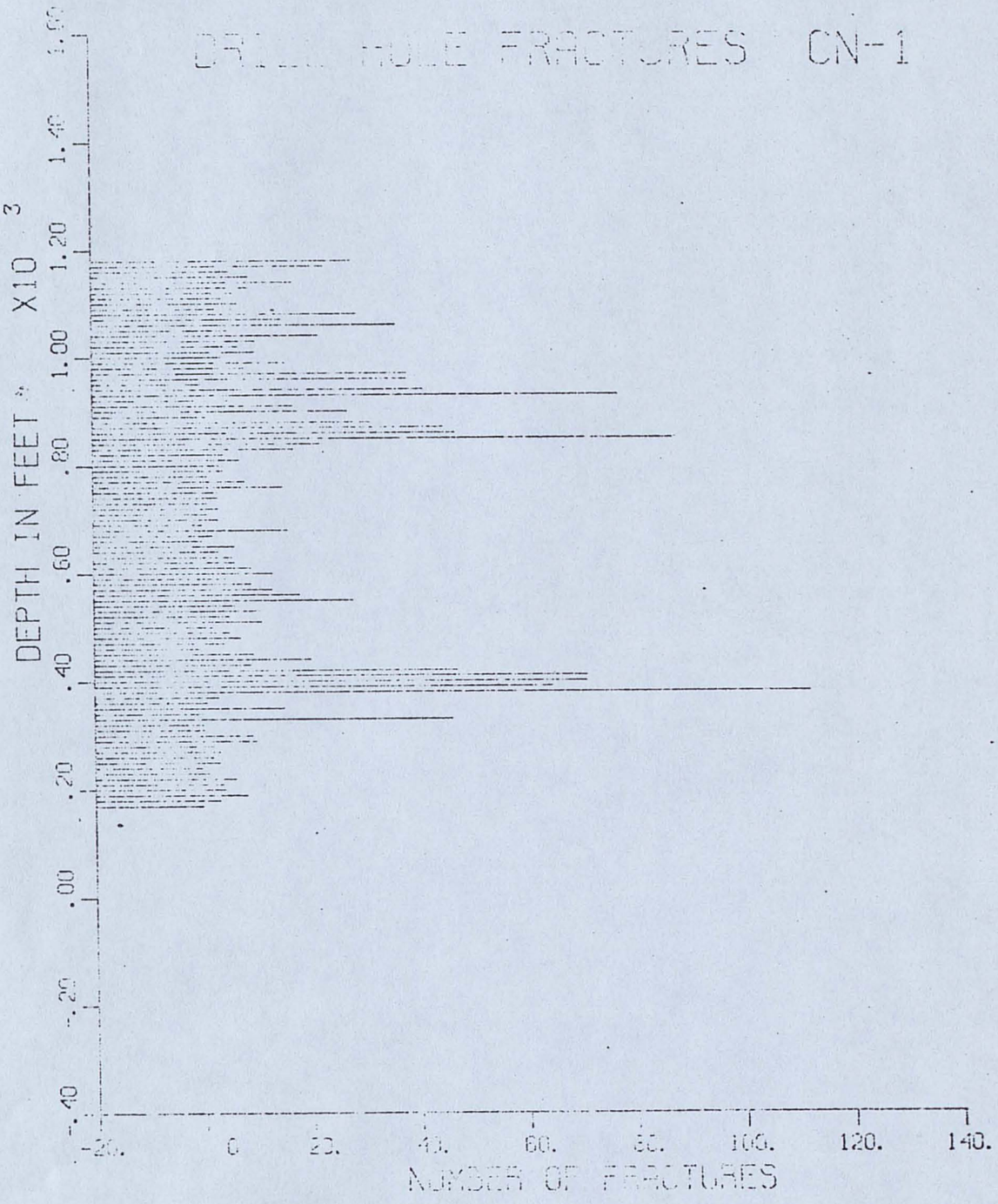
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.00
-.20
-.40
-20.
0
20.
40.
60.
80.
100.
120.
140.
NUMBER OF FRACTURES

DEPTH IN FEET
40.
80.
120.
160.
200.
240.
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320.
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32.0
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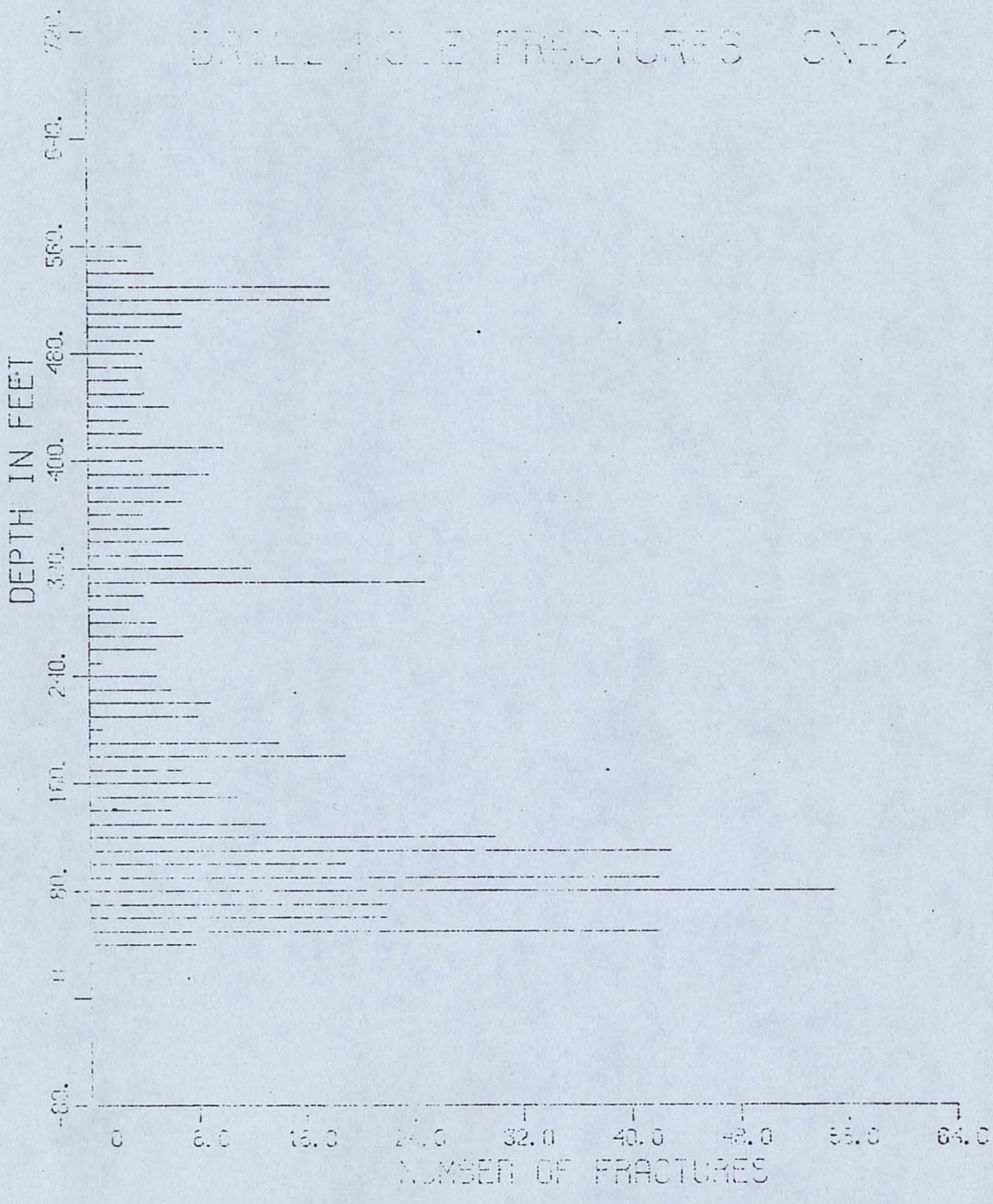
DRILL HOLE FRACTURES CY-2
DEPTH IN FEET
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480.
400.
320.
240.
160.
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32.0
40.0
48.0
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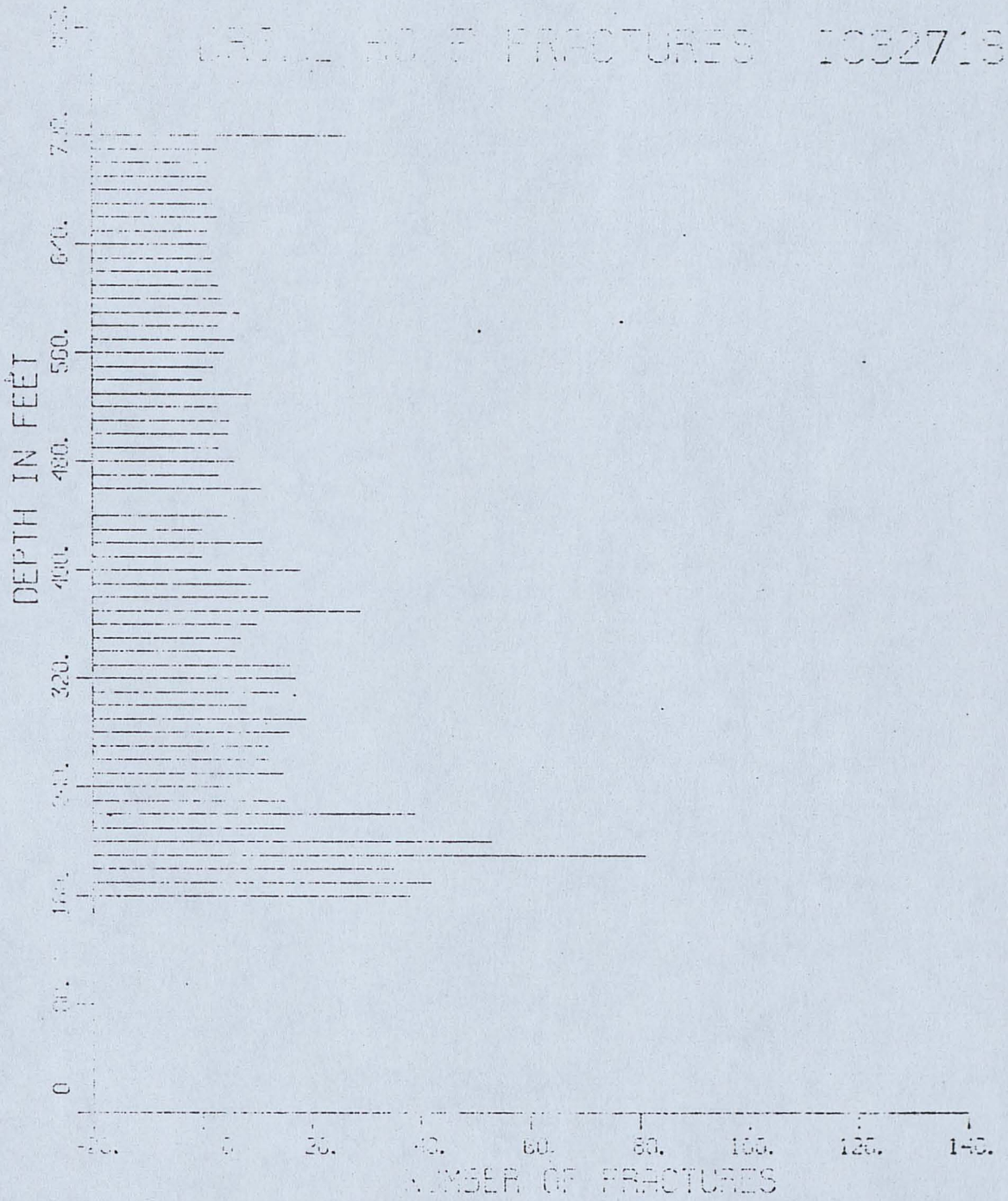
64.0
NUMBER OF FRACTURES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20.
40.
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100.
120.
140.
NUMBER OF FRACTURES

DEPTH IN FEET X10 3
1.40
1.20
1.00
.80
.60
.40
.20
.00
-.20
-.40
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16.0
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56.0
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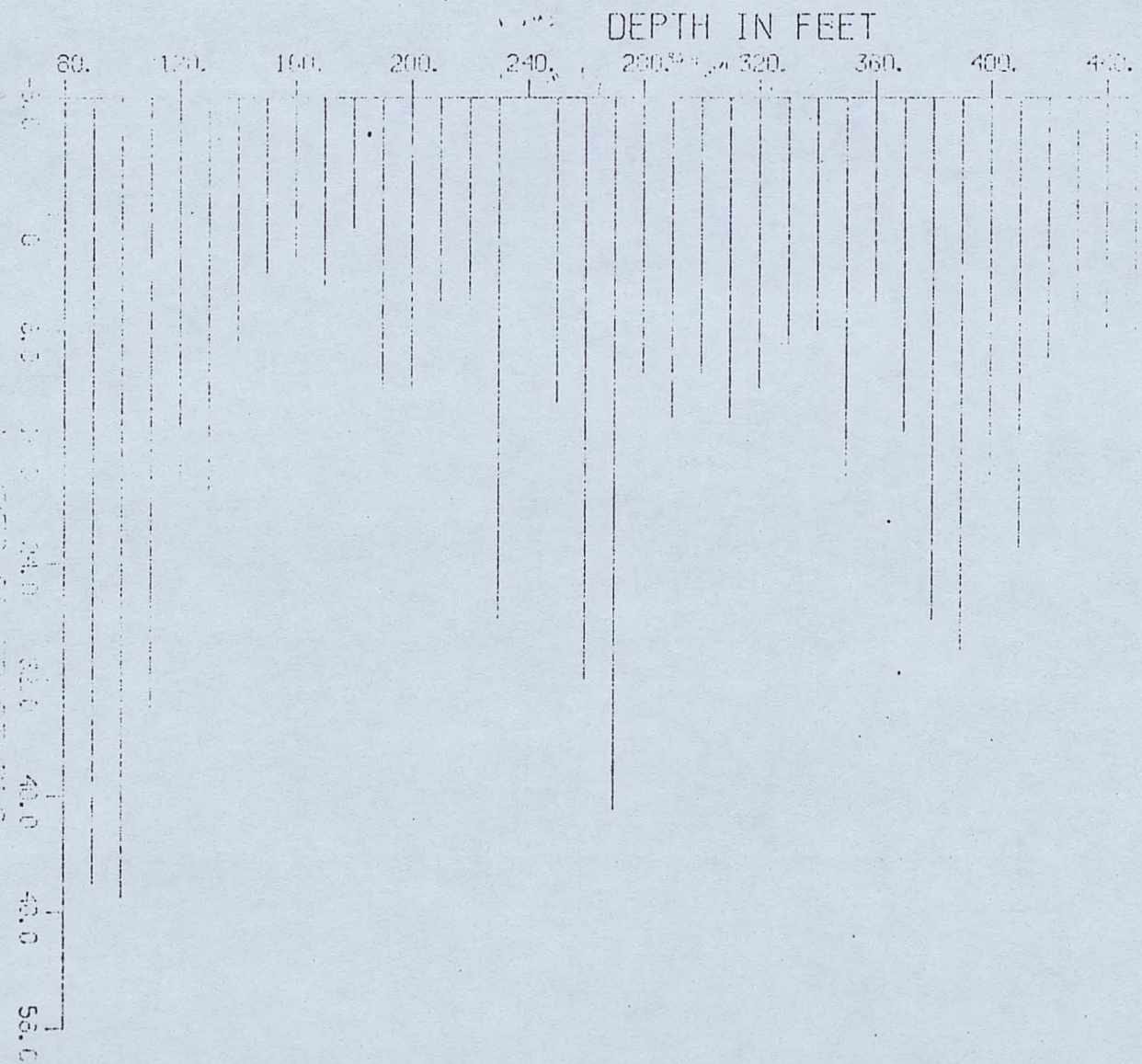
NUMBER OF FRACTURES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56.0

FRACTURES A4-4
DEPTH IN FEET
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80.
160.
240.
320.
400.
480.
560.
640.
720.
0
20.
40.
60.
80.
100.
120.
140.
160.
NUMBER OF FRACTURES

IN32727A
DEPTH IN FEET
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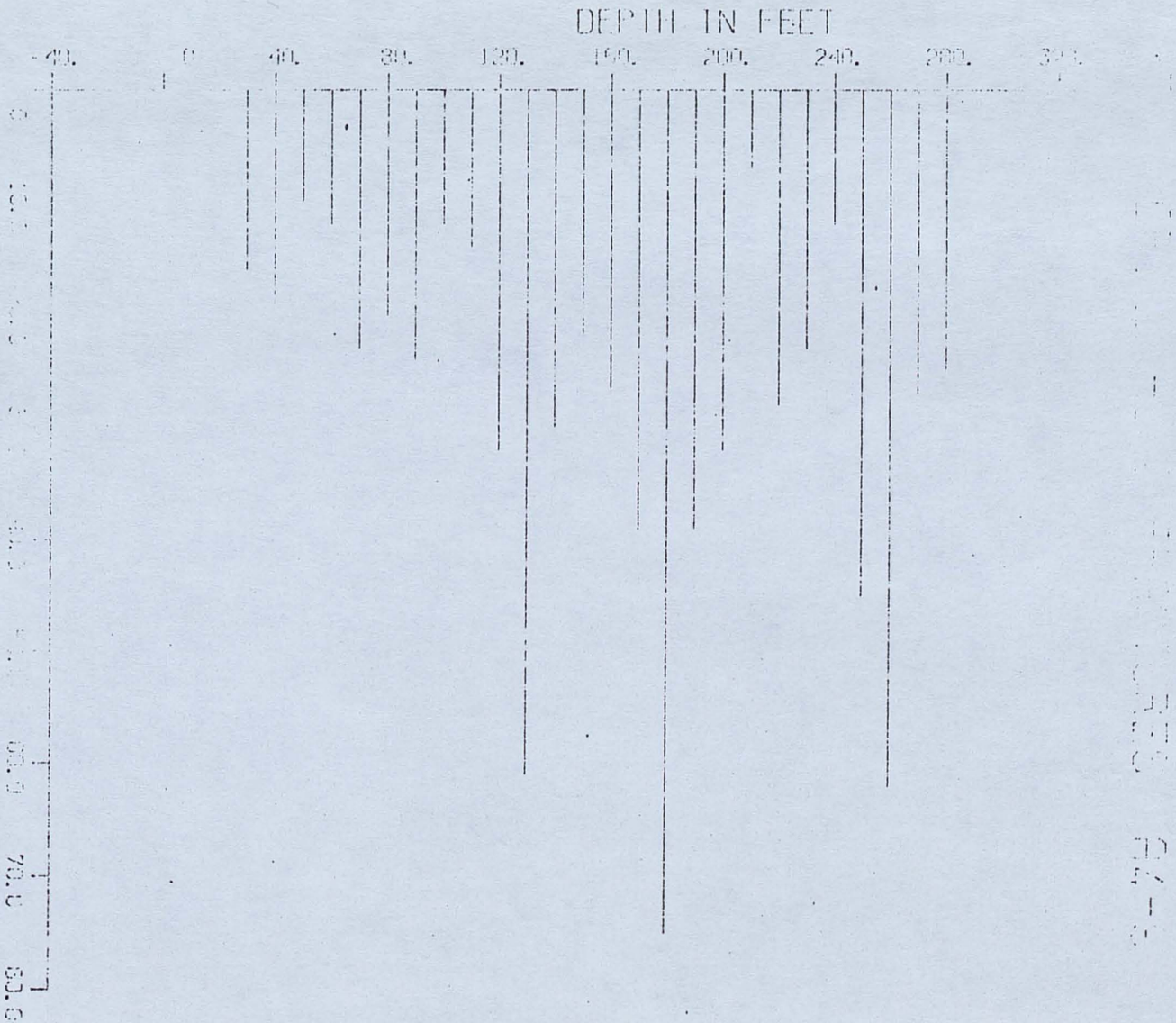

DEPTH IN FEET
-40.
0
40.
80.
120.
160.
200.
240.
280.

PART 4

PART 5

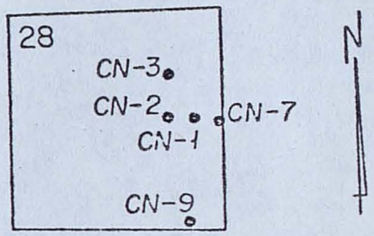
Summary of fracture and rock type data based on computer coded raw data (Part 1) from drill cores in the southwest part of the Hoyt Lakes area

DRILL HOLE	DEPTH INTERVAL	ROCK TYPE	TOTAL FOOTAGE	TOTAL FRACTURES	FRACTURES PER FOOT
A4-1	0-40	OV	40		
	40-90	TR-3	50	425	8.500
	90-250	TR1-TR2, S	160	385	2.406
	250-565	TR-1	315	902	2.863
CN-2	0-30	OV			
	30-70	PD-3	40	94	5.925
	70-350	PD-1	280	453	1.618
	350-560	HF	210	135	.643
CN-3	0-70	OV	70		
	70-260	TR-3	190	235	1.237
	260-300	PD-1	40	77	1.925
	300-310	TR-2	10	14	1.400
	320-460	HF-1	140	210	1.500
CN-9	0-70	OV	70		
	70-130	AN-3, TR-3	60	159	2.650
	130-210	TR-3, PC	80	495	6.188
	210-220	06-3, DY, S	10	17	1.700
	220-460	06-3, DY	240	210	0.875
	460-690	TR-3, PD,S	230	283	1.230
	690-750	TR-1	60	124	2.067
IC32718	0-150	OV	150		
	150-440	TR-3, HF	290	559	1.928
	440-720	TR-3	280	119	0.425
IN32727A	0-20	OV	20		
	20-440	TR-1, AN	420	244	0.581
	440-840	TR-2 S	430	551	1.281
	890-920				

Summary of fracture and rock type data based on computer coded raw data (Part 1) from drill cores in the southwest part of the Hoyt Lakes area

DRILL HOLE	DEPTH INTERVAL	ROCK TYPE	TOTAL FOOTAGE	TOTAL FRACTURES	FRACTURES PER FOOT
IC32730	0-20	OV	30		
	20-700	TR-3	680	415	0.610
	700-1140	TR,S	440	713	1.620
A4-4	0-20	OV	20		
	20-360	TR-2,S	340	731	2.150
	360-380	PD,S	20	24	1.200
	380-410	SE	30	19	0.300
	420-460	TR-3,S	40	257	6.425
	460-470	SE	10	26	2.600
	470-610	TR-3,5	140	953	6.807
	610-690	TR-2,S	80	385	4.813
	690-730	TR, HF	40	201	5.025
A4-6	0-40	OV			
	40-190	TR-3, AN	100	186	1.240
	190-380	MF-1, TR2	190	451	2.394
A4-8	0-20	OV			
	20-500	TR-3, PD	480	1609	3.352
	500-770	M-1, S	270	626	2.319
A4-9	0-20	OV			
	20-50	M-2, S	30	45	1.500
	50-100	M-2	50	91	1.820
	100-280	M-1, S	180	476	2.644
NM-11	0-30	OV			
	30-1542	TR, M-3	1512	3496	2.312
A1-1	0-20	OV	20		
	20-340	PD-3	320	271	0.847
	340-416	AT-2	76	90	1.184
A3-5	0-70	OV	70		
	70-300	M-3	230	352	1.530
	300-650	TR-2	350	284	0.811
	650-1190	TR-1, S	540	696	1.289
	1190-1321	TR-1, HF	131	470	3.588

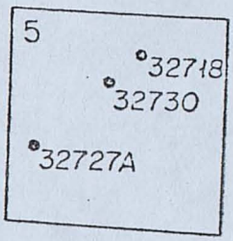
PART 6

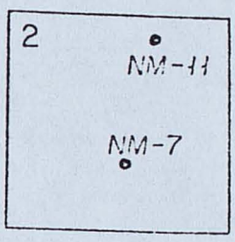


T.57N. R.14W.

Sec. 28

Water Hen





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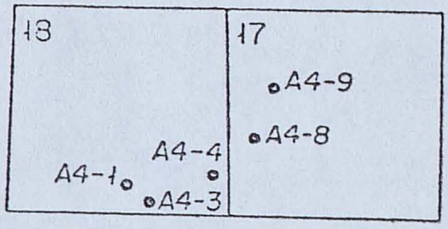
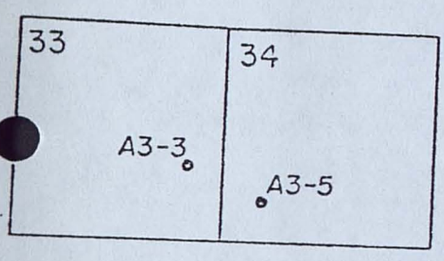
T. 60 N. R. 12 W. | T. 60 N. R. 11 W.

N





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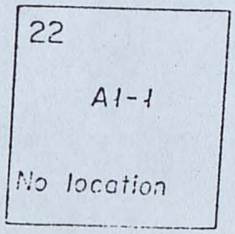
T.58N. R.14W. | T.58W. R.13W.

N



Sec. 22

APPENDIX IV

Textural and compositional characteristics of sulfide ores from the basal contact zone of the South Kawishiwi intrusion, Duluth Complex, Northeastern Minnesota by P.W. Weiblen and G.B. Morey, Minnesota Geological Survey Reprint Series 32, 1976.

MINNESOTA GEOLOGICAL SURVEY
SAINT PAUL, MINNESOTA

PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF NATURAL RESOURCES

Map No. 1
Bedrock Geology
Hoyt Lakes-Kawishiwi Area
1:48,000
MGS/DNR

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1525 East Third Avenue
Hibbing, MN 55746

HOYT LAKES - KAWISHIWI AREA, ST. LOUIS AND LAKE COUNTIES, NORTHEASTERN MINNESOTA

Bedrock Geology

EXPLANATION

Upper Precambrian — Duluth Complex — Troctolitic Series rocks

- d — Diabasic rocks, undivided
- tr — Granophyre of Bonnichsen, 1971
- tg, tf — tg, troctolite to gabbro segmatite; tf, flow-layered troctolite and gabbro
- fg — Ferrogabbro of Bonnichsen, 1971
- tbg, tbt — Bald Eagle intrusion of Weiblen, 1965; tbg, gabbroic rocks; tbt, troctolitic rocks
- tpg — Powerline Gabbro of Bonnichsen, 1974
- tpt — Partridge River troctolite of Bonnichsen, 1974
- tsg, tt, tcz — South Kawishiwi intrusion of Green et al., 1966; tsg, troctolite with ~5 % augite throughout; tcz, contact zone rocks characterized by sulfides and heterogeneous rock types; tg, contact zone gabbro south of Birch Lake
- tr — Railroad troctolite of Bonnichsen, 1974
- tu — troctolitic and/or gabbroic rocks, undivided
- mha — mixed troctolite and anorthositic rocks of uncertain origin

Anorthositic Series rocks

- f, agp, agg, agu, p — f, granophyric rocks, undivided; agu, anorthositic gabbro, undivided; agp, anorthositic gabbro with clusters of pyroxene, olivine, and/or oxides; agg, gabbroic anorthosite having ~5 % hypersthene; p, peridotitic and noritic rocks, undivided
- h, hf — Inclusions in Duluth Complex: h, hornfels, undivided; hf, Biwabik-type iron-formation

Contact (solid, known; dashed, inferred; dotted, concealed by water)

Contact (inferred from geophysical data)

Strike and dip of foliation

Vertical foliation

Minor folds (showing plunge of axis)

Approximate southern limit of extensive outcrops in Duluth Complex

Individual outcrops in southern part of map area

Fault (solid, known; dashed, inferred; dotted, concealed by water)

Fault (inferred from geophysical data)

Strike and dip of bedding

Inclined

Inclined, right side up

Inclined, overturned

Vertical

Vertical, top in direction of dot

Trend of beds top in direction of arrow

Horizontal bed or foliation

Upper Precambrian — Middle Precambrian

- b — North Shore Volcanic Group, undivided
- v, bif, pq — v, Virginia Formation; bif, Biwabik Iron Formation; pq, Pokegama Quartzite

Middle Precambrian

- gr — granitic rocks, undivided
- vg, vam — vg, biotite granite and granite-rich migmatite; vam, foliated admixture and migmatite
- gab, ggb, gmh — Giants Range Granite: ggb, equigranular biotite granite and adamellite; gpb, porphyritic hornblende adamellite and monzonite; gmh, hornblende monzonite and adamellite
- tj — tri-mica gneiss
- bs — biotite schist
- am — amphibolite
- bg, tbg, mig, ami — Metamorphosed rocks: bg, quartzose biotite gneiss; tbg, coarse-grained, layered leucocratic migmatite; mig, gneiss intruded by fine-grained leucotrondjemite; ami, amphibolite inclusions

Vermilion massif

Lower Precambrian

- qp — Quartz porphyry
- vmt, vtv, vig — Lake Vermilion Formation: vmt, tuff breccia with interbeds of volcanic sandstone; vmt, dominantly felsic agglomerate and breccia; vtv, felsic volcanic rocks; vig, interlayered amphibolitic, biotitic and felsic gneiss
- nlm, nlu, nls, nlct, nlt, nlf, nld, nlp — Newton Lake Formation: nlb, dominantly basaltic lava flows; nlt, felsic tuff breccia; nlf, felsic flows; nls, volcanic sedimentary rocks; nli, banded iron-formation; nlm, siliceous marble; nlp, peridotite; nlct, crystal tuff; nld, diabasic gabbro; nlu, mafic and intermediate volcanic rocks, undivided
- kg, kvm, kvf — Knife Lake Group: kg, lithic greywacke and argillite; biotite schist (south of Fall Lake); kif, banded iron-formation; kvf, felsic volcanic rocks (mainly tuff and agglomerate); kvm, mafic volcanic rocks
- mg — metagreywacke and slate, undivided

Ely Greenstone

- euf, eui, eub — Upper member: eub, basaltic lava flows; eud, metadiabase; eui, banded iron-formation; euv, variolitic basaltic lava flows; euf, felsic lava flows; eus, carbonaceous siliceous siltstone
- elb, eli — Lower member: elb, dominantly basaltic lava flows; eli, banded iron-formation

Geology modified by G.B. Morey and R.W. Cooper from published and unpublished geologic maps indicated in index to mapping.

SCALE

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INDEX TO MAPPING

1. Bonnichsen, B., 1968, General geology and petrology of the metamorphosed Biwabik Iron formation, Dunka River area, Minnesota: unpub. Ph.D. thesis; Univ. of Minn., Mpls., 240p.
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14. Phinney, W.C., 1967, Geologic map of a part of the Kangas Bay quadrangle, Minnesota, showing the Duluth Gabbro Complex, 1:24000: Minn. Geol. Survey, open-file map.
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Base from U.S. Geological Survey 1:24000: Allen, 1969; Aurora, 1969; Babbitt, 1969; Babbitt-NE, 1969; Babbitt SE, 1969; Babbitt SW, 1969; Bear Island, 1965; Ely, 1965; Embarrass, 1969; Isaac Lake, 1969; Kangas Bay, 1965; Shagawa Lake, 1965. 1:62500: Brimson, 1957; Gabbro Lake, 1957; Greenwood Lake, 1954; Markham, 1957.

MINNESOTA GEOLOGICAL SURVEY
SAINT PAUL, MINNESOTA

PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF NATURAL RESOURCES

Map No. 2
Data-Base Map
Hoyt Lakes-Kawishiwi Area
1:48,000
MGS/DNR

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HOYT LAKES - KAWISHIWI AREA, ST. LOUIS AND LAKE COUNTIES, NORTHEASTERN MINNESOTA

Data - base Map

EXPLANATION

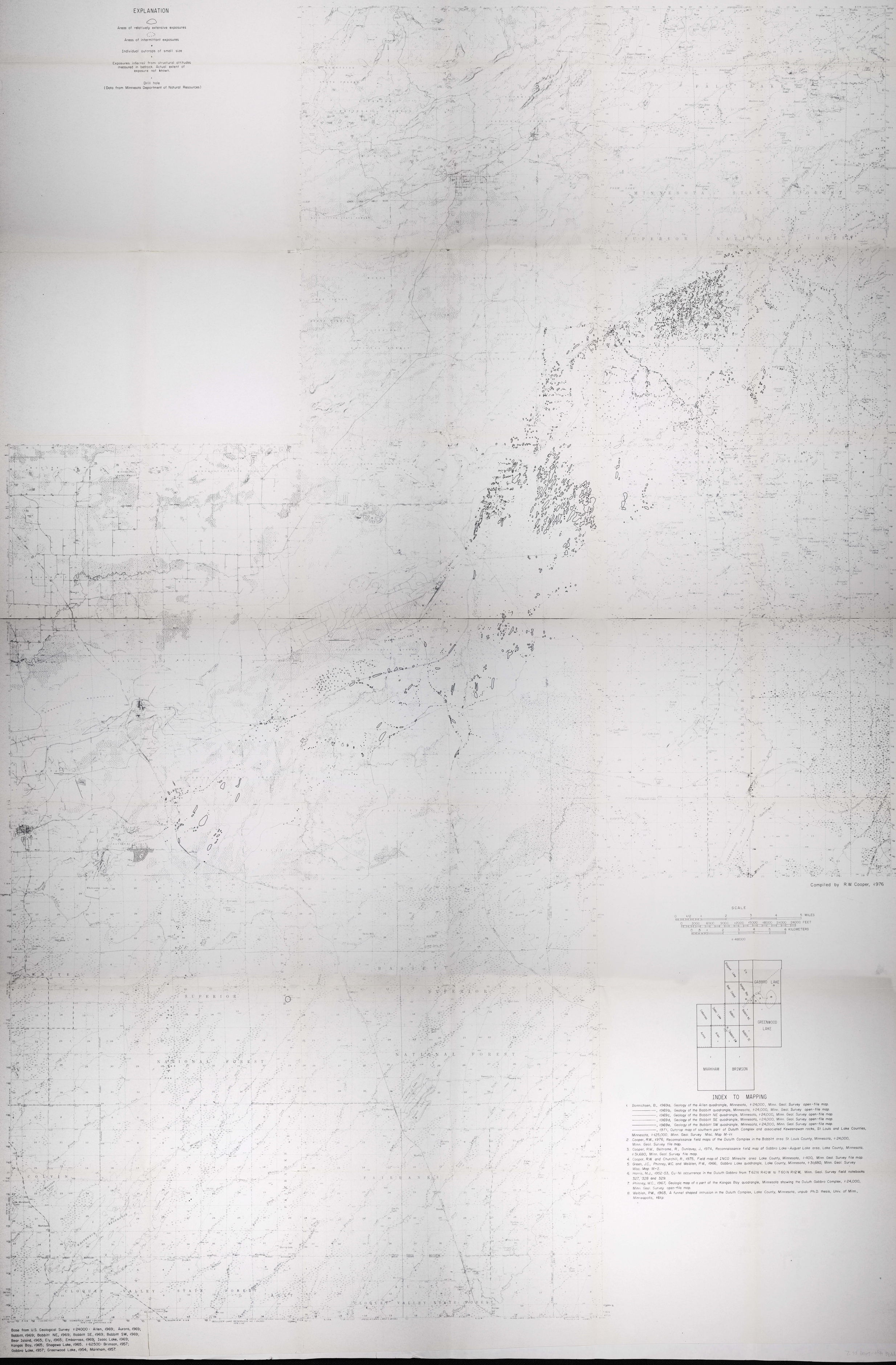
Areas of relatively extensive exposures

Areas of intermittant exposures

Individual outcrops of small size

Exposures inferred from structural attitudes measured in bedrock. Actual extent of exposure not known.

Drill hole
(Data from Minnesota Department of Natural Resources)



Compiled by R.W. Cooper, 1976

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INDEX TO MAPPING

1. Bonnichsen, B., 1969a, Geology of the Allen quadrangle, Minnesota, 1:24,000, Minn. Geol. Survey open-file map.
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———, 1969d, Geology of the Babbitt SE quadrangle, Minnesota, 1:24,000, Minn. Geol. Survey open-file map.
———, 1969e, Geology of the Babbitt SW quadrangle, Minnesota, 1:24,000, Minn. Geol. Survey open-file map.
———, 1971, Outcrop map of southern part of Duluth Complex and associated Keweenawan rocks, St Louis and Lake Counties, Minnesota, 1:125,000. Minn. Geol. Survey Misc. Map M-11.
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8. Weiblen, P.W., 1965, A funnel shaped intrusion in the Duluth Complex, Lake County, Minnesota, unpub Ph.D. thesis, Univ. of Minn., Minneapolis, 161p.

Base from U.S. Geological Survey 1:24000: Allen, 1969; Aurora, 1969; Babbitt, 1969; Babbitt NE, 1969; Babbitt SE, 1969; Babbitt SW, 1969; Bear Island, 1965; Ely, 1965; Embarrass, 1969; Isaac Lake, 1969; Kangas Bay, 1965; Shagawa Lake, 1965. 1:62500: Brimson, 1957; Gabbro Lake, 1957; Greenwood Lake, 1954; Markham, 1957.

2 id 5052-1-94 Plate1

MINNESOTA GEOLOGICAL SURVEY
SAINT PAUL, MINNESOTA

PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF NATURAL RESOURCES

Map No. 3
LINEAMENT MAP
HOYT LAKES-KAWISHIWI AREA
1:48,000
MGS/DNR

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HOYT LAKES - KAWISHIWI AREA, ST. LOUIS AND LAKE COUNTIES, NORTHEASTERN MINNESOTA

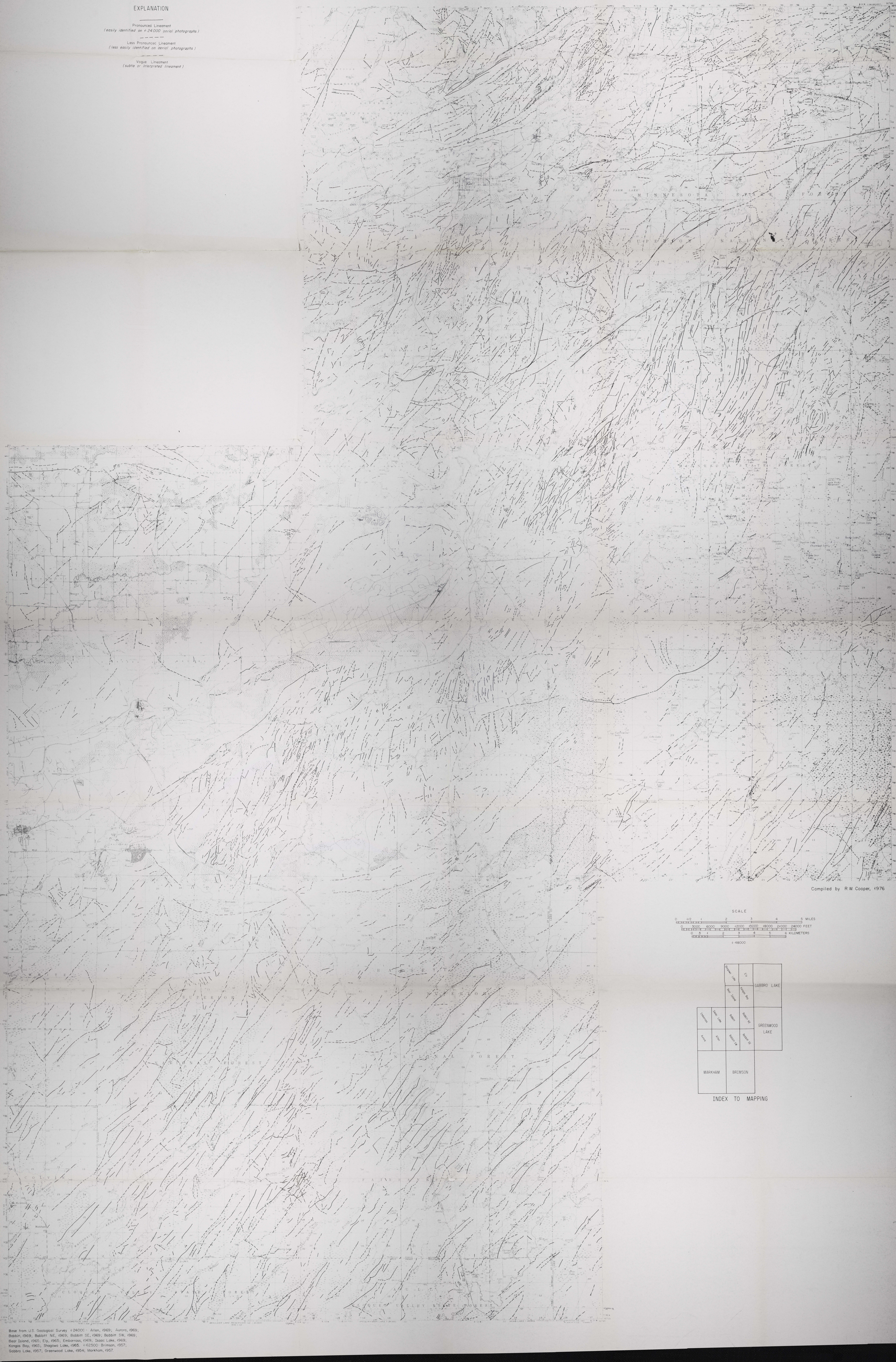
Lineament Map

EXPLANATION

Pronounced Lineament
(easily identified on 1:24000 aerial photographs)

Less Pronounced Lineament
(less easily identified on aerial photographs)

Vague Lineament
(subtle or interpreted lineament)



Base from U.S. Geological Survey 1:24000: Allen, 1969; Aurora, 1969; Babbitt, 1969; Babbitt NE, 1969; Babbitt SE, 1969; Babbitt SW, 1969; Bear Island, 1965; Ely, 1965; Embarrass, 1969; Isaac Lake, 1969; Kangas Bay, 1965; Shagawa Lake, 1965. 1:62500: Brimson, 1957; Gabbro Lake, 1957; Greenwood Lake, 1954; Markham, 1957.