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Pegmatites of the Anderson Ridge quadrangle, Fremont County, Wyoming

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PEGMATITES OF THE ANDERSON RIDGE QUADRANGLE, FREMONT COUNTY, WYOMING

BY

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A

THESIS

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ABSTRACT

The oldest rocks in the area consist mainly of paraschists of low to medium rank and restricted higher rank sillimanite schist. The entire series has been at least double folded. The most apparent are tight north to northeast trending folds. These have been intruded in the northern part of the area by a batholithic body of granitic composition, a granitic stock, a pegmatitic granite, a granitic sill-like body and different types of pegmatite dikes and sills. The youngest intrusions are a series of northeast trending basic dikes and sills. A major easterly trending transverse fault and a series of smaller faults of almost east-west trend are the main fault trends in the area. They are younger than all bodies above.

Pegmatites are very abundant and vary in size, shape, texture, and mineralogy. They are more numerous in the north than the south and invade all rock types except the younger basic intrusions.

A new classification of the size, shape, and texture of pegmatites is proposed. The size and shape of any individual pegmatite body is identified by two values, namely, the length X width (LXW) value and the length/width (L/W) ratio. Because of the extreme variation in texture of the pegmatite bodies a classification based on a geometric scale is proposed. Both mega- and microscopic sizes

applicable to field and laboratory studies are included.

Five different mineralogical types of pegmatites are recognized: magnetite granite, graphic granite, tourmaline granite, garnet granite, and biotite granite.

Both concordant and discordant types of pegmatites are present. A few of the concordant varieties show a rough zoned character, but layering is characteristic of the discordant and many of the concordant varieties. The layering may result from textural and/or compositional variations. Coarse and very coarse bands alternate with fine and very fine ones. Also distinct mineralogic variations are common in these different bands. Fine-grained red garnet-rich bands characterize a good percentage of the pegmatites in the area. These colored bands are of great help in determining the internal structure of such bodies.

The pegmatites are believed to be of magmatic origin. The temperature of the magmatic fluids, the content of volatiles, and the confining pressure as well as the chemical composition are thought to have varied greatly for the different pegmatite types of the area.

Beryl is the most important economic mineral known to date. The very coarse tourmaline granite pegmatites are the most important host for beryl. Coarse perthitic bands and massive quartz bands in the tourmaline garnet granite pegmatites and the garnet granite pegmatites offer some promise as hosts for beryllium minerals.

The district is now under active exploration.

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I. INTRODUCTION

A. Location of area

The pegmatite area of Anderson Ridge quadrangle is situated in the south central part of Fremont County in central Wyoming. It lies about thirty-five miles south of Lander, the county seat, about 5 miles west of the historic gold-mining town of South Pass and about 18 miles south of the Atlantic City taconite deposit. Latitudes 42° 22' 30"N and 42° 30'N and longitudes 108° 52' 30"W and 109° 00' W bound the area. (See figure 1).

Main access to the area is State Highway 28 from Lander and/or Farson, Wyoming. This highway is a few miles east of the northern part of the area and cuts diagonally across the southeast corner of the quadrangle. Numerous dirt roads connect the highway and different portions of the pegmatite area. In addition to those roads shown on the Anderson Ridge 7 1/2 minute quadrangle sheet of 1953, recent mining activities in the area have resulted in the construction of other improved dirt roads.

Elevations in the area range from 7500 feet to more than 8000 feet above sea level. In general, the northern part is higher than the southern portion. The continental divide lies in the southwest corner of the area where it trends approximately northwest-southeast.

The area is characterized by rolling topography of relatively low relief. Minor erosional variations in the topography are a result of the diversity of rock types.

Figure 1. Index Map of Wyoming Showing Tectonic Setting of Anderson Ridge Area.
(After U.S.G.S. and A.A.P.G., 1962)

These range from the knobby and rounded granitic and pegmatitic masses to the fairly smooth terrane of the metamorphic rocks. The Sweetwater River and its tributaries drain this portion of the Wind River Range. The major streams are incised several hundreds of feet into the Precambrian rock units. The main stream is at least partly fault controlled where it crosses the southern portion of the area. Jack, Gold, and Sharps Meadows creeks along with other small tributaries of the Sweetwater River are classified as subsequent streams.

The area is almost completely covered by sage brush ranging from one to more than three feet in height. Tree cover, conifers and aspen, is mainly confined to the northern apart of the area and the major stream valleys. Grass covered meadows occur in many of the stream valleys and in the vicinity of small springs. Throughout the area different lichens of vivid colors usually encrust the different, otherwise barren, rocks. The extreme northern edge of the area studied is included in the Shoshone National Forest and the Bridger National Forest.

In the past, and at present, most of the area has been used for grazing sheep and cattle. An abundant water supply and grassy meadows make the land ideal for this purpose. The area near Jack's Ranch has been the center of this industry.

Exploration of the abundant pegmatite bodies was initiated within the past year. At least three groups are now engaged in exploration and mining development. The possibility exists that mining could become an additional industry in the area.

B. Objectives of study

Lack of information on a hitherto unknown pegmatite area in southwestern Wyoming suggested the need for detailed investigation of the area.

The main purpose of the investigation was to determine the types of pegmatites present, their size, their mineralogical and structural characteristics, and their possible economic potential. Because of the internal layered character of the pegmatite bodies some emphasis was placed on this phase of the study. An attempt was also made to give a more useable classification as to their size, shape, and grain size characteristics. (Fig. 2)

C. Field and Laboratory Work

The Anderson Ridge area of the Wind River mountains is exceptional because of the abundance and variation of the pegmatite intrusives and their distribution within the igneous and metemorphic country rocks.

During the summer of 1961, Professor Paul Dean Proctor of the Missouri School of Mines and Metallurgy and Professor Clayton H. Johnson of the University of Missouri conducted a reconnaissance study of the Anderson Ridge quadrangle and

Figure 2. Anderson Ridge area from sec. 31,T.29N., R.101W., looking south, showing the general rolling topography and the white patchy outcrops of pegmatites.

outlined the basic geologic features. Preliminary work was started on the structure and mineral deposits of the area. Later in the season the area was used as a mapping exercise for the University of Missouri field camp students. Proctor continued the study for two weeks after the field camp period. In Spring, 1962, Professor Proctor outlined a research project on the pegmatite deposits because of their character, abundance, size, and possible economic potential.

During this period a photogeologic study was made of the Anderson Ridge quadrangle. In July, 1962, the author began a field check and research on the various pegmatites in the area. This was carried on during the month. Professor Proctor joined the writer and the field phase was brought to completion after two more weeks of field work. Mapping in the field was on aerial photographs of the U. S. Geological Survey at a scale of about 1/20,000. Detailed sketches and maps of individual pegmatites were prepared at 1" =100', 1" =50', 1" = 25', 1" = 4', or less depending on the detail required. Compilation of the field data was made on the 1/24,000 Anderson Ridge quadrangle base of the U.S.G.S., 1953.

Laboratory work on thin sections, polished sections, and spectrographic analysis was completed during the fall and winter of 1962-63.

D. Previous work

As far as is known nothing has been written on the geology of the Anderson Ridge quadrangle or its pegmatites. Indeed, very little has been published on the Precambrian complex of the Wind River Range. However, past mining activity to the east of the area and recent work on the well known Atlantic City taconites has resulted in several publications on these areas. The gold-mining district of South Pass drew the attention of geologists when gold was first discovered in 1842 (Beeler, 1908)*. Several reports were written in the first decades of the twentieth century giving geologic data and reasons for the decline of the mining activity. Knight (1901), Beeler (op. cit.), Jamison (1911), Trumbull (1914), and Spencer (1916) were the main contributors of this period. These reports describe, in general, the main geologic features of the region, the mode of occurrence of the gold, and the various intrusive rocks. Trumbull includes in his report a geologic sketch map of the area at a scale of about 1.5 miles/inch. Spencer also includes a somewhat more refined geologic map at a scale of about 1.2 miles/inch. His southwest map boundary ends about 2 miles from the northeast corner of the Anderson Ridge quadrangle.

*Refers to references included in bibliography at the end of thesis.

Of 51 master and doctorate theses written on areas within Fremont County only a few concern themselves with the Precambrian complex. The most important of these are by Laguna (1938), McLaughlin (1939), Armstrong (1948) and Kolb (1951).

In general, publications dealing with the stratigraphy and structure of the Wind River mountains and the adjacent basin usually give broad general statements on the Precambrian rocks e.g. Branson et al (1941) then details on the younger strata and structures.

Very little has been written on the pegmatites of Wyoming. However, McLaughlin (1940) studied in detail the pegmatite dikes of Bridger Mountain in northeast Fremont County about 80 miles north northeast of the Anderson Ridge quadrangle. Hanley et al (1950) studied the pegmatite areas of the Copper Mountain district in northeast Fremont County. and the Haystack Range district in Goshen County. They compare and correlate these pegmatites with those in Colorado and Utah. No data were given for the pegmatites in the Wind River mountains.

Giletti et al (1961) ran a number of absolute-age determinations on different Precambrian rocks in north, central, and southeast Wyoming as well as southwest Montana, Utah, and South Dakota. These rocks are mainly pegmatites and gneisses. Their work shows that there are possibily 2 main generations of pegmatites, one ranging from 2720 to

2540 million years (m.y.) ago and the other from 1760 to 1580 m.y. A pegmatite sample from Peat Lake, northern Wind River range gave an age of 2540 m.y. and another from Wind River canyon gave 2720 m.y. A quartz monzonite sample from southern Wind River range gave 2370 m.y.

Oftedahl (1953) mentioned the existence of migmatites and agmatites in the northwestern part of the Wind River Range. He describes in some detail their petrography and their genesis. Parker (1962) published a short report on the agmatites and agmatite migmatites of the Wind River mountains in an area about 30 miles to the north northwest of the Anderson Ridge quadrangle.

Currently research is in progress by R. Bayley of the U. S. Geological Survey (personal communication, 1962) on the Precambrian rocks of the South Pass quadrangle directly to the east of the Anderson Ridge quadrangle, by P. D. Proctor and C. Johnson of the University of Missouri (personal communication, 1962) within the quadrangle, and by R. Whorl and D. Hodges of the University of Wyoming (personal communication, 1962) in and adjacent to the area studied.

E. Acknowledgements

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II. REGIONAL GEOLOGIC SETTING.

A. General Statement.

This study is mainly concerned with the pegmatites of the Anderson Ridge area. In order to aquaint the reader with the general geologic setting a brief summary is presented of the major geologic features and their relationships. Details on the general geology of the area are from Proctor and Johnson (personal communication, 1962) and the work of the author.

The Anderson Ridge quadrangle comprises a portion of the Wind River Precambrianscomplex. The oldest rocks consist mainly of paraschists which range in metamorphic rank from low to medium except for restricted occurrence of higher rank sillimanite schist. At least one earlier series of folds have been cross-folded into tight north-south to northeast folds. These have been intruded in the northern part of the quadrangle by a batholithic body of granitic composition. Contact relationships with the schists is in most cases gradational. Other intrusions are represented by a granitic stock, a pegmatitic granite, a sill-like granite body, and different types of pegmatite dikes and sills. These latter will constitute the main body of this thesis. The youngest known intrusions are a series of basic dikes and sills. Major faulting in the area is represented by an easterly trending transverse fault in the northern part of the quadrangle. A series of faults of lesser displacement and almost east-west trend occur in the Sweetwater River area in the west central portion of the quadrangle. Details of the lithology and structure are in progress by Proctor and Johnson (personal communication, 1963) and the writer. The generalized geologic map (Plate 1) is taken from this work.

B. Metamorphic rocks.

The metamorphic rocks consist of biotite-and sericite-quartz schists, garnet-mica-quartz schists and staurolite(?) quartz schist. (See figures 3, 4, and 5) The mica, and the less abundant chlorite-quartz schist, probably represent more than 70% of the metamorphic rocks present. Locally the garnet schist is abundant. Distinctive biotite-quartz schists rich in "peanut"-like inclusions are conspicuous throughout the area (figure 6). The "peanuts" are usually much darker than the enclosing schist and may even be black. They are elongate and range in size from about 0.2 inches to more than one inch. Sillimanite schist and minor other schists are also present locally. The schists may contain bands and lenses of recrystallized quartz which has been remobilized during metamorphism. Some amphibolites are present, especially in the northwest part of the quadrangle. These probably represent older intrusions which have been metamorphosed with the geosynclinal sediments of the region.

Microscopic study shows that the main composition of the biotite-quartz schist is quartz, biotite and some plagioclase and potash feldspar. The garnet-mica-quartz

Figure 3. Sweetwater sericite-quartz schist outcrop, sec. 24, T. 28N., R. 102W.

Figure 4. Folded biotite-quartz schist, sec. 8,T. 28N., R. 101W., jointed and containing quartz lenses.

Figure 5. Drag folds in sericite-biotite-quartz schist, Sec. 17,T.28N., R101W. (See p. 18)

Figure 6. "Peanut" schist, NW$\frac{1}{4}$, sec.33, T.29N., R.101W.

has generally the same composition as the biotite schist but also contains red almandine garnet. The latter of a variable size, although generally averages about 3 mm. in diameter. The "peanut" schist has the normal mineral composition of the biotite schist. Some of the knobby metacryts consist of sillimanite and muscovite elongate in the direction of schistosity. Others show fresh poikilitic feldspar crystals with quartz and biotite as the main inclusions.

C. Igneous rocks.

The major intrusive lies in the northern part of the quadrangle and represents the southern margin of a probable batholith as yet unmapped. Microcline, sodic plagioclase, biotite and quartz are the main constituents. The biotite granite ranges from coarse to fine-grained and sometimes is porphyritic. The granite-metamorphic rock contact is in most cases gradational through a series of gneisses and "dirty" or contaminated granite. This zone may be up to one mile wide. Well developed foliation of the dark minerals and schlieren arevisible in the contact zone of the granite (Figure 7).

Two small granitic bodies crop out as stock-like bodies within the metamorphic schists. A biotite granite mass occurs in the west-central portion of the quadrangle and is named the Sweetwater stock (Proctor, personal communication, 1962). Average mineralogic composition is sodic plagioclase, microcline and some orthoclase together with biotite,

Figure 7. Schlieren in granite, SE$\frac{1}{4}$, sec. 22, T.29N., R.102W.

Figure 8. Anderson Ridge gabbro sill, showing spheroidal weathering boulders, SE$\frac{1}{4}$, sec. 31,T. 29N., R101W.

muscovite and quartz. Feldspar is usually partly altered to sericite and clay minerals. Some biotite has been chloritized and epidote is common in minor amounts as a probable alteration product. The other granitic body is a pegmatitic granite that crops out in the east-central part of the quadrangle. This eastern stock extends beyond the quadrangle boundary. The stock and the pegmatites are rich in garnet. A third much smaller granitic body of sill-like form crops out in the northwestern portion of the quadrangle in sections 22 and 23. It may represent an extention of the northern batholith or a conformable projection off a larger igneous body to the west.

D. Pegmatites

The mapped pegmatites are generally of granitic composition and many are rich in garnet. The texture varies greatly and likewise the size of the bodies themselves. Individual pegmatite may range from a few inches in width and length to bodies several hundred feet in width and thousands of feet in length. Both concordant and discordant bodies are present. Mineralogical types include: magnetite granite, graphic granite, tourmaline granite, garnet granite and mica granite. Details are included in the following sections.

E. Basic dikes and sills

Basic intrusions appear to be the youngest intrusive bodies in the area. These are gabbroic in texture and composition but may grade into dolerite and even basalt-like bodies. These intrusives cut the older rock types and form dikes. In the southern part of the area several parallel the schistosity and bedding and form large sill-like bodies. The intrusions range to several miles in length and more than 100 feet in width. Their trend is generally northeast. The dikes and sills vary in width along the strike. Locally plug-like feeders may attain 300 feet. Bifurcation of the main bodies into smaller branches is not uncommon. Spheroidal weathering and exfoliation are common weathering phenonenon (Figure 8).

Under the microscope the composition is mainly calcic plagioclase and augite. The plagioclase feldspar appears fresh while the augite usually shows reaction rims of hornblende and sometimes of biotite. Magnetite appears as a reaction product. The mafic minerals are often altered to chlorite.

F. Structural setting

The major folded structures in the area consist of almost isoclinal folds. Small parallel to sub-parallel drag folds are also present. (See fig. 5). At least two periods of folding and cross folding have been recognized. The general trend of the major cross-fold axes is indicated on plate I (after Proctor and Johnson, 1962).

A major easterly trending fault and a series of smaller faults with a general E-W trend occur within the area. The main fault cuts the folds, the granite, pegmatites, and basic dikes, and extends eastwards into the South Pass gold-mining district (R. Bayley, F. El Baz, personal communication, 1962). While the fault zone is not conspicuous in the field, a shallow valley does parallel the fault trend. Outcrops of breccia to mylonite zones up to 300 feet wide are locally exposed along the fault zone. To the south, smaller transverse faults occur in the Sweetwater River area in the west central part of the quadrangle. These appear to have influenced the drainage pattern of the main streams. They also displace some of the pegmatite bodies and basic dikes.

Several different sets of joints have been recognized. This is especially true in the granite bodies. (Fig. 9). These fractures form well developed systems in the northern granitic body. The conspicuous knobby character of the outcrops in the National Forest to the north is joint controlled. (Fig. 10). The schists also show well developed joints and fracture cleavage. Most of the pegmatite bodies are not faulted, but in most cases they are well jointed and sheared. Details of jointing in some pegmatites will be discussed later.

G. Late Hydrothermal Activities

1. Epidotization.

Late stage epidotization is mainly confined to the northern part of the quadrangle and mainly to the eastern half of the granitic body. On a local scale it also affects

Figure 9. Jointing and sheeting in Sweetwater granite stock, looking east, NW$\frac{1}{4}$, sec.3, T. 28N., R.102W.

Figure 10. Jointing in porphyritic biotite granite, main granite batholith, SE$\frac{1}{4}$, sec. 10T. 29N.,R.101W.

the pegmatites and the basic intrusions. Epidote (pistachite) occurs along cracks and fractures in these rocks and forms micro- to macroscopic veinlets and patches. Most intense and pervasive epidotization is present in section 15, T29N, R101W, where up to 60% of the host granite rock may be converted to epidote. Epidotized zones have been cut by the main transverse east-west fault mentioned above. The late mineralization was guided by earlier joints and fractures in the area.

2. Copper mineralization.

A few scattered showings of copper staining by malachite and azurite occur within the area. The most conspicuous are in section 21, T29N and R101W near the fault, and in the NW¼ sec. 17, T29N, R101W adjacent to a basaltic dike. No detail work was done on these occurrences.

III. PEGMATITES OF THE ANDERSON RIDGE QUADRANGLE

A. General statement

Abundance and variation of pegmatites in the Anderson Ridge area are rather remarkable. Indeed, the number of the pegmatites of the different types is so large that the term "pegmatite swarm" seems appropriate.

Pegmatites invade all the older rock types except the younger basic intrusives. Relative abundance of the pegmatites is as great in the main granite body as in the schists, although individual bodies are somewhat smaller. Within the metamorphic rocks the pegmatites do not appear to favor one type of schist over another.

Plant cover is scarce or absent on the pegmatite bodies compared to the surrounding rocks and as a result they are usually well exposed. Locally, however, some very low sage brush and occasional trees grow along fractures and joint lines within the bodies (See fig. 11 and 12).

In general, the northern portion of the area contains more pegmatites than the southern and the pegmatite swarm extends west of the quadrangle boundary. Eastwards the pegmatites are less in number. They also decrease in number southwards and finally disappear under a cover of Tertiary gravels.

B . Size and shape

The extreme variation in size and shape of pegmatite bodies is a well known fact. Pegmatites can range in width

Figure 11. General outcrop pattern, garnet granite pegmatite, sec. 34, T.29N., R101W.

Figure 12. Garnet granite pegmatite, notice scanty vegetation on the pegmatite, sec. 34,T.29N., R.101W.

and length from few inches to several thousand feet. In the published literature on pegmatites different terms have been introduced to describe the shape of these bodies, e.g., dike, funnel, lens, pod, teardrop, bulbous, sinuous, tabular....etc. But none of these is well defined and different authors may describe one and the same body by different terms or may use one and the same term to describe differently-shaped bodies.

In this study a geometric classification, worked out by the author and Professor Proctor, is used in order to eliminate meaningless descriptive terms and apply only a few well defined terms. This classification takes into consideration the factors of size and shape and is applicable where the pegmatite bodies assume a generally regular geometric form. Its base is mainly two-dimensional and depends on the surface outcrops of the pegmatites. While this is a defect in the classification, it is a fact that observations in the third dimension except for erosional relief, are in most cases insufficient or unavailable.

The length (L) X width (W) value and the length/width ratio are the two parameters used. The "length" and "width" represent the longest and the shortest exposed dimensions of any regular shaped pegmatite body. A pegmatite with length X width value equal or less than 2000 square feet is considered small, that with L X W value more than 2000 square feet and less than 20,000 square feet and that with a value of more than 20,000 square feet are called moderate and large respectively. With regard to shape a pegmatite with length/width ratio between 1 and 2 is called rounded or square depending on the expressed geometric form, with a ratio more than 2 and less than 5 is considered oval or rectangular, with a ratio more than 5 and less than 10 is taken as elongate while that with a ratio of more than 10 is very elongate. For example, a pegmatite with a length X width value of, say, 3000 square feet and a length/width ratio of 7 will be described as moderate elongate...etc. In case of branched or irregular pegmatites it is possible to subdivide the individual pegmatite bodies into more or less geometric units. The average length X average width value and the composite length/composite width of the different units can be used as the parameters. The modifying term "irregular" may be used in describing the shape of these pegmatites e.g. irregular oval pegmatite....etc.

A summary of the statistical analysis of the Anderson Ridge pegmatite area is given in figure 13. The frequency of each size and shape is demonstrated in that figure by a dot or square representing a pegmatite (or a number of pegmatites) observed and recorded in the field.

As statistically shown, the pegmatites in the area under discussion range from small to large and from rounded to very elongate. The shapes are not constant though a large percentage have a tendency to be elongate. (See Plate II). The general elongation direction is northeastward and mainly guided by the prominent foliation and bedding.

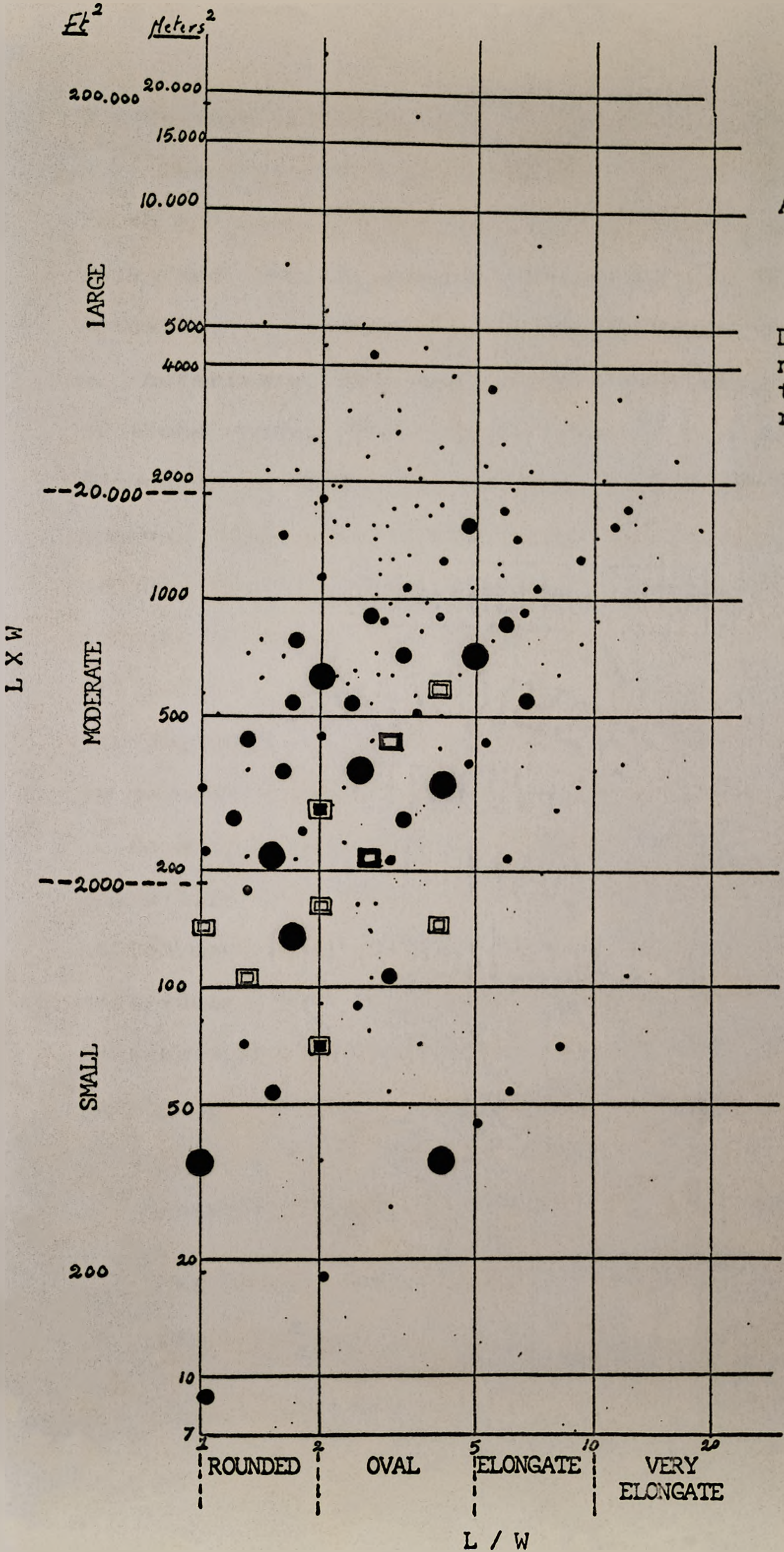


Figure 13

Statistical Analysis of Anderson Ridge Pegmatites Fremont County, Wyo.

EXPLANATION

Dots and squares represent number of pegmatites of the same LxW value and L/W ratio.

•	1	pegmatite
•	2-5	pegmatites
●	6-10	pegmatites
●	11-20	pegmatites
▢	21-30	pegmatites
■	31-40	pegmatites
▣	41-50	or more pegmatites

[Scale Logarithmic]

C. Texture

The pegmatites are generally characterised by coarse to very coarse-grained texture compared to other igneous rocks and this is generally described as pegmatitic texture. Actually, it is not only the coarse-grain size which is characteristic, but also the very wide range of variation of these sizes. The largest crystals or grains may be thousands or even millions times larger than the smallest grains. This problem was recognized during the development of this thesis. There does not appear to be a conventional texture classification for pegmatites. For example, Hanley et al (1950, p.4) gave a general megascopic classification for pegmatites. According to their classification pegmatites or pegmatite zones with an average grain size of 2 inches or less are considered fine-grained, ones with average grain size more than 2 inches and less than 1 foot are called medium-grained and those with average grain size of more than 1 foot are called coarse-grained. For more normal igneous rocks Travis (1955), following the lead of other petrographers (e.g., Johannsen, 1939) gives the following classification for igneous rocks:

Coarse-grained....composed of grains more than 5mm. in diameter.

Medium-grained....composed of grains 1-5mm. in diameter

Fine-grained......composed of grains less than 1 mm. in diameter

For a non-conflicting terminology it seems that the Hanley, _et al_ megastopic classification cannot apply also to microscopic sized grains. This conflicts with Travis and earlier petrographers who applied these grain sizes to microscopic measurements of grains, not to macroscopic grains of the dimmensions known in pegmatites.

In 1960, Olson _et al_ in their study of the pegmatites of Nevada and Arizona followed a quite reasonable field grain size classification based on the maximum dimension of each grain. Their system is as follows:

Very fine............less than 1/8 inch

Fine.................1/8 to 1 inch

Medium...............1 to 4 inches

Coarse...............4 to 12 inches

Very coarse..........more than 12 inches

The writer only partly agrees with the above mentioned authors on the class limits in the largest grain sized range. For the fine microscopic sizes it is quite clear that there is a large range of sizes below 1/8 inch. It does not seem proper to lump all sizes below this limit in just one class, or to use texture terms of igneous rocks (pegmatites) which have already been pre-empted for the plutonic and volcanic rocks.

The problem of classification of the variation in texture in pegmatites is comparable to that of sedimentary rocks. In these rocks, an ordinary linear scale is unsatisfactory. A graduated or logarithmic scale was used for the textural classification of sedimentary rocks. Such a scheme is proposed for pegmatite textures. In such a scale larger units are used for the larger sizes and smaller units for the smaller sizes. The Udden or Atterberg grade scale can be used (Pettijohn, 1957, p. 28). The first scale is based on 1 mm. as the starting point and uses the ratio 1/2 or 2 (depending on the sense of direction). The Atterberg scale is based on a decimal system beginning with 2 mm.

The following proposed classification of pegmatites grain sizes follows the Udden system (Udden, 1898) and the class limits are modified after Wentworth (1922). No connotation, is given as to origin and the scale is geometric only. Note also that for pegmatites the terms very fine, fine, medium...etc. are used as modifiers of the noun pegmatite only.

Table 1. Classification of grain size for pegmatites

Size in mm.	Proposed term for texture of pegmatites
...	
...	very coarse
256	
128	
64	
32	coarse
16	
8	
4	
2	medium
1	
1/2	
1/4	
1/8	fine
1/16	
1/32	
1/64	
1/128	very fine
1/256	
.....	
.....	

As mentioned above, the variation in texture in one and the same pegmatite is usually the rule rather than the exception. To help in this matter it is proposed that such names as equigranular, porphyritic and pegmatitic can be applied as modifying terms. These, too carry only a geometric connotation. In other words the texture will be described by two terms one denoting the grain size and the other the variations in such grain sizes in the same pegmatitic mass, e.g., medium equigranular pegmatite. The term "equigranular" can be used when the overall grain size is equal while the terms porphyritic and pegmatitic are applied in case of the grain size (diameter) ratio of the coarse-grained to the fine-grained material is between 2 to 5 or more respectively.

The pegmatites of the Anderson Ridge quadrangle vary greatly in texture. A large portion demonstrate an overall medium*texture while others are very coarse. The former group occurs mainly in the central part of the quadrangle and is, for the most part, garnet bearing. The very coarse pegmatites are less abundant and have almost constant mineralogical composition and are usually beryl-bearing. In an individual pegmatite the texture may show considerable variations. Usually in the small elongate and very elongate pegmatites the central portion of the body is much coarser than the periphery (porphyritic) although sometimes the peripheral zone is as coarse as the central part (equigranular).

*The use of the terms coarse, medium, fine...are henceforth used as proposed in Table 1.

In the moderate to very large oval to elongate bodies the textural variation is much more complicated (porphyritic to pegmatitic) and sometimes quite irregular.

The outcrop pattern and the surface expression of the pegmatites vary with the grain size variations and local structures. The small to moderate and elongate to very elongate pegmatites usually parallel and sometimes alternate with the schist and generally follow its surface expression (fig. 14). In the granite terrane the pegmatites tend to follow certain fracture and foliation planes. In some cases the small oval pegmatites are actually off-shoots of the large and the very large masses. The moderate to very large pegmatites may be low-lying and show little surface expression. Yet, some do have knobby outcrops up to more than 30 feet higher than the surrounding country rocks. Pegmatites with the least surface relief are generally coarse to very coarse-grained. The high knobby-weathering pegmatites are for the most part garnet-bearing and of almost medium-grained texture. These latter bodies are mainly located in the central and eastern part of the quadrangle. The topographic and surface expression of the pegmatites in the granite are usually not characterized by conspicuous protruding outcrops.

B. General mineralogical types and distribution characteristics.

Several mineralogic types of pegmatites were recognized in the geologic study of the area and their spatial distribution ascertained. The following are the main types:

Figure 14. Intercalation of pegmatites and schist, Sweetwater bank, sec.13,T.28N.,R.102W.

1. Magnetite granite pegmatites
2. Graphic granite pegmatites
3. Tourmaline granite pegmatites
    a. Very coarse tourmaline-beryl-bearing granite pegmatites
    b. Medium to fine tourmaline-bearing granite pegmatites
4. Garnet granite pegmatites
5. Biotite granite pegmatites

1. Magnetite granite pegmatites

The magnetite granite pegmatites are mainly confined to the northern granitic terrane (see fig. 15 and 16). These pegmatites range from small to moderate and rarely large and from rounded to elongate. Texture is generally medium equigranular to porphyritic. Main mineralogical composition is microcline, sodic plagioclase, quartz, magnetite, minor epidote and sometimes chloritized biotite. Garnet is rare or absent.

Under the microscope the sequence of crystallization shows that most of the sodic plagioclase and some microline are the first crystallized. These minerals are almost completely altered to sericite and minor epidote. A newer generation, mainly of fresh microcline, is usually associated with quartz. Microcline in this case is mainly perthitic.

Different types of perthites are recognized, the most abundant of these are the film, string and vein types (Anderson, 1928). (Figures 17 and 18). Also present is a

Figure 15. Small magnetite-bearing granite pegmatite, sec. 16,T.29N.,R.101W.

Figure 16. Low-lying granite pegmatite with fine hematite streaks, Sweetwater stock, sec.3,T.28N.,R.102W.

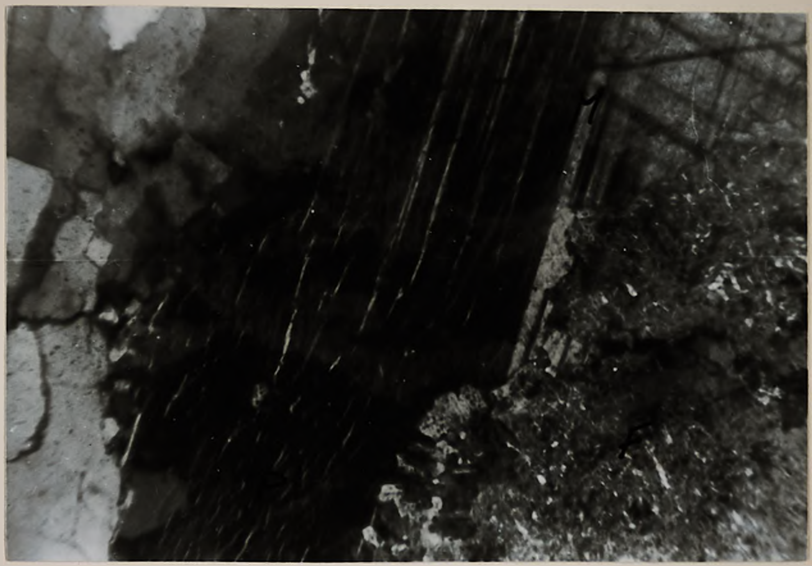


Figure 17. Magnetite granite pegmatite showing highly altered feldspar (F), microcline (M) and film perthite (P). X-nicols, 80X.

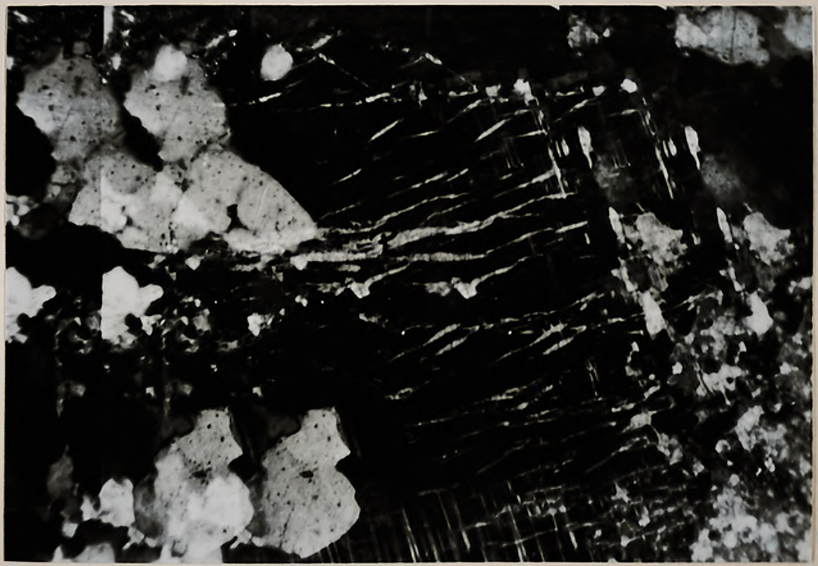


Figure 18. Magnetite granite pegmatite showing vein perthite (P). X-nicols, 80X.

network patchy-type of perthite. Quartz usually fills the spaces between the feldspar crystals and in cavities and cracks within them. Quartz may be contemporaneous and/or later than the fresh microcline. The above mentioned feldspar and quartz are cracked and fractured to different degrees, and sometimes very badly brecciated, granulated and/or micro faulted. Undulatory extinction is not uncommon. The broken areas are filled mainly by fine-grained quartz. Green epidote, variety pistachite, is usually associated with this last generation of quartz. This pistachite forms small veinlets and patches. The amount present is variable. Magnetite grains are usually scattered throughout the pegmatite bodies. In most cases these are surrounded by a halo of hematite discoloration. Magnetite grains range to 2 cm. in diameter.

Figure 19 shows a sketch plan view of a rounded magnetite pegmatite (Pegmatite No. 1*) with patchy inclusions of "dirty granite" that also constitutes the surrounding country rock. This type of inclusion is much more common in the rounded and oval pegmatites than the elongate type. The two geologic sections of this pegmatite show the typical equigranular texture characteristic of these magnetite-bearing pegmatites.

*Refers to sequential number of specific pegmatites studied in detail and their location shown in Plate II

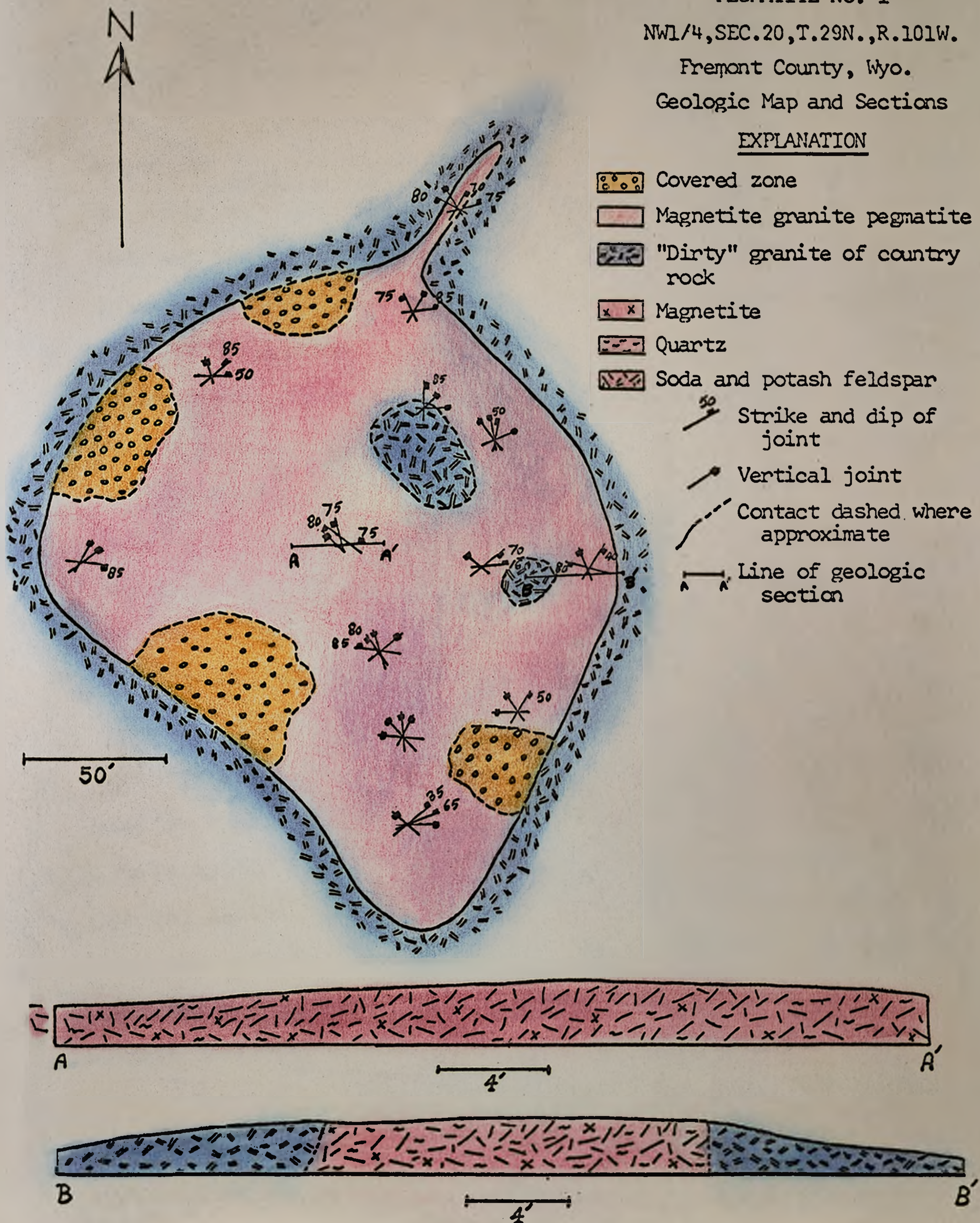
Figure 19

PEGMATITE No. 1

NW1/4,SEC.20,T.29N.,R.101W.

Fremont County, Wyo.

Geologic Map and Sections



2. Graphic granite pegmatites

Graphic granite pegmatites are of local distribution and occur mainly in the northwestern part of the quadrangle, especially in Sections 22 and 23, T.29N., R102W. For the majority of these pegmatites the country rock is a sill-like body of biotite granite. The latter may represent an outlier of a much larger body to the west of the main northern granite body. The pegmatites tend to follow the predominant directions of joints. And the pegmatite-granite contact is in all cases sharp and well-defined.

These graphic granite pegmatites vary from small to moderate and rarely large. In shape, they vary from oval to elongate. Texture is coarse to very coarse, and pegmatitic.

The mineralogical composition is rather simple and consists of perthitic microcline and quartz in a macroscopic graphic structure with or without minor amounts of muscovite and/or biotite. Individual intergrowths may contain quartz blebs up to 8 mm. in diameter and the feldspar may exceed 30 cm. in length. Under the microscope, the main perthites are the vein and string types. The quartz blebs are usually composite with individual grains as large as 4mm. in diameter. These commonly show wavy extinction. Very small (-.5 mm.) minor muscovite flakes may be associated with this quartz. Well developed megascopic graphic intergrowths are characteristic of these pegmatites (See fig. 20).

The graphic granite pegmatites, senso stricto, change

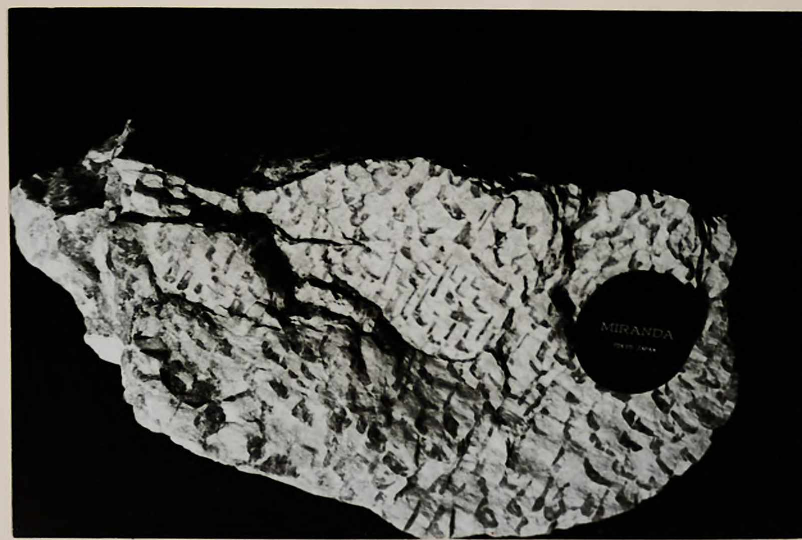


Figure 20. Graphic intergrowth of quartz and microcline, NW$\frac{1}{4}$, sec. 29, T.29N., R.101W. Camera lens-cover shows scale.

Figure 21. Tourmaline-beryl-granite pegmatite (Pegmatite No. 2) NW$\frac{1}{4}$.sec.29, T.29N., R.101W., showing tourmaline (T), biotite (B), Quartz (Q), and feldspar (F).

laterally outside the sill-like granitic mass into tourmaline and/or garnet-bearing pegmatites with or without graphic texture. If present, the graphic granite is usually confined to one or more coarse to very coarse bands within the body.

3. Tourmaline granite pegmatites

Tourmaline granite pegmatites are mainly present in the central part of the quadrangle, especially in a zone extending northeastward. Outside this main zone minor tourmaline may or may not be present in the garnet granite pegmatites. Another tourmaline bearing zone occurs in the northwestern portion of the area, mainly in the southern parts of sections 23 & 24, T. 29N., and R.102W. Visible tourmaline decreases in abundance outside these zones, especially southwards, and is almost absent in Secions 11 and 20, T.28N., R.101W.

Individual crystals of tourmaline vary greatly in size. These range from a few millimeters to about 20 centimeters in length and up to 6 centimeters in diameter. The larger tourmaline is usually euhedral to subhedral and the crystals usually show the characteristic triangular cross section. They are generally fractured and cracked. The tourmaline is invariably the black schorlite variety (Fig. 21).

At least two main types of tourmaline granite pegmatites are recognized: (a) very coarse-grained tourmaline beryl-bearing granite pegmatites and (b) medium to fine-grained tourmaline granite pegmatites.

a. Very coarse-grained tourmaline beryl-bearing granite pegmatites

The very coarse-grained tourmaline and beryl-bearing granite pegmatites are the coarest-grained bodies in the quadrangle (Fig. 22). They vary from small to moderate and usually are oval to elongate. Texture is very fine- to very coarse-grained, pegmatitic. The mineralogical composition is generally constant and consists mainly of albite to oligoclase plagioclase, microcline, and golden to brown biotite mica together with muscovite and anhedral quartz. The predominant feldspar is the chess-board albite (Anderson, 1928, P. 151) and microcline showing different types of perthites of mainly the vein and string varieties (Figures s26 & 27). Microcline is usually cross twinned with many variations in the coarseness and fabric of the twin texture. Untwinned microcline is also often seen.

The size of the mica varies and may range to more than 30 cm. in diameter (Fig. 23). These masses usually develop parallel to the cleavage and the smooth surfaces of the feldspar crystals. Biotite is golden brown but sometimes dark brown or even black (ferruginous variety). Muscovite may have a pinkish or greenish tint.

Quartz ranges from white and milky to very dark smoky but predominantly is slightly smoky. It is patchy in character and present as megascopic intergrowths within or without the feldspar. In the former case it forms a graphic

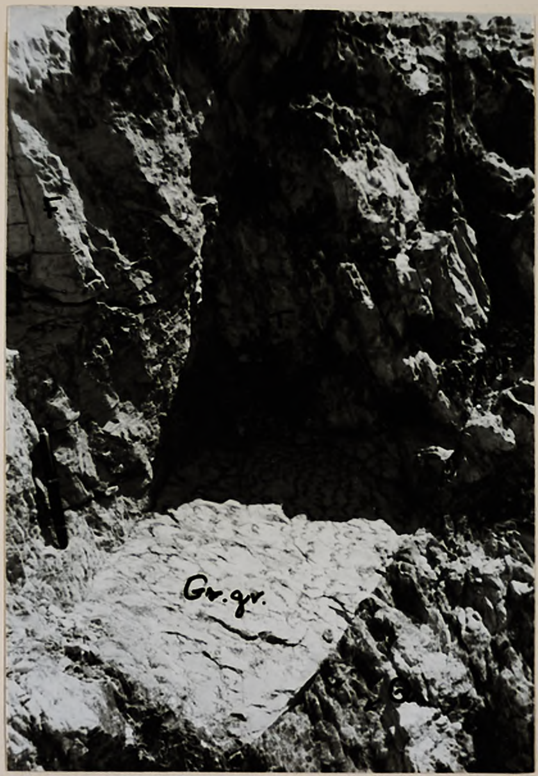


Figure 22. Tourmaline pit, (Pegmatite No. 4) showing tourmaline (T), quartz (Q), feldspar (F) and graphic granite (Gr. gr.), sec. 31,T.29N., R .101W.

Figure 23. Mica pit (Pegmatite No. 12), showing contact with the schist and alternation of muscovite "books" and feldspar, sec. line 1-2, T.28N., R102W.

texture. Schorlite is abundant and usually occurs in patchess and clusters more in direct contact with the quartz than the feldspar. Redalmandine garnet to 1.5 mm. or larger may be locally present in clusters and small patches. Beryl is usually euhedral, in this type of pegmatite. The known crystals range from less than 1 cm. in diameter and less than 2½ cm. in length to more than 8 cm. in diameter and more than 20 cm. in length. A beryl crystal about 40 cm. in diameter and not less than a meter in length has been recorded in recent mining operations (Fig. 24). Feldspar crystals may attain coarse sizes sometimes exceeding 80 cm. in length. Rather well developed crystals are present (Fig. 25). The feldspars sometimes show megascopic perthite structures and/or graphic intergrowths (Fig. 26).

b. Medium- to fine-grained tourmaline granite pegmatites

Two varieties of the medium- to fine-grained tourmaline granite pegmatites are present. The first type has a characteristic spotted appearance for the tourmaline, and the second type has garnet as an accessory mineral with the tourmaline.

i. Spotted tourmaline granite pegmatites

The spotted tourmaline granite pegmatites are of local distribution. They are mainly confined to the northeast part of the quadrangle mainly in sections 20, 21, 28 and 29, T.29N., R.101W. They have also been noted in section 2,T.28N.,R102W.

Figure 24. Tourmaline-beryl-granite pegmatite, (Pegmatite No. 3) sec. 31, T.29N., R.101W., notice large beryl crystal under pen.

Figure 25. Euhedral microcline (perthite) crystal (Pegmatite No.2), NW$\frac{1}{4}$, sec. 29,T.29N.,R.101W. Camera lens-cover shows scale.

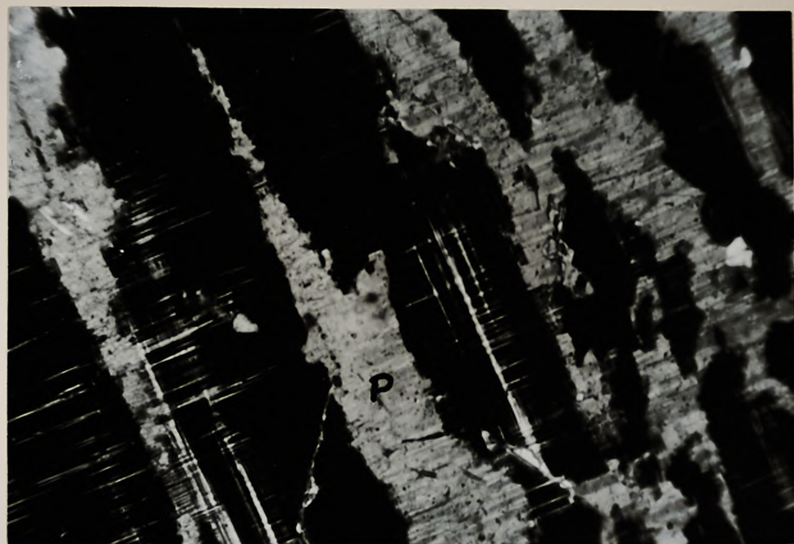


Figure 26. Tourmaline pit (Pegmatite No.4), showing vein perthite (P) .X-nicols, 80X.

Figure 27. Spotted tourmaline pegmatite showing anhedral tourmaline (T). Matrix is sodic plagioclase (P), untwinned microcline (M) and quartz (Q).X-nicols,80X.

The bodies are usually small to moderate and oval to elongate. A major exception to this is the contorted pegmatite body in the northwest corner of section 28,T.29N.,R.101W. which is large in size and rounded in shape. Texture is very fine to coarse, equigranular (saccharoidal) to porphyritic. Tourmaline occurs in small spots and patches about 1 cm. or less in diameter scattered throughout the pegmatite (Fig. 21). This imparts a black spotted character to the outcrop. The intensity and frequency of these tourmaline masses and spots varies irregularly through the same pegmatite body. In these pegmatites the tourmaline is anhedral and shows a poikilitic texture; enclosing and surrounding partly or completely feldspar grains in most cases. Frequently the tourmaline crystals are disrupted and fill spaces between the other mineralogical constituents. Beside tourmaline, the main components are sodic plagioclase, mainly albite (about .2 - .5 mm. in diameter), microcline nearly of the same grain size as the plagioclase, and showing perthitic structure commonly of the vein type, and minor shreds of muscovite (about .2 - 1 mm. or more in diameter).

ii. Tourmaline garnet granite pegmatites

The tourmaline garnet granite pegmatites are common in the central part of the quadrangle. Their texture and mineralogical composition is similar to the garnet granite group with the exception that they contain tourmaline.

Tourmaline of the schorlite variety is mainly present in minor amounts and is usually fine to coarse in size. It occurs in small clusters and in irregularly distributed aggregates not exceeding 3 or 4 cm. generally, but sometimes up to 10-15 cm. Details or size, shape, and texture of these pegmatites is included in the description of the next group.

4. Garnet granite pegmatites

The garnet granite pegmatites make up the majority of the pegmatites in the Anderson Ridge area.(Fig. 11 and 12). They are especially common in the center and the east-central portions. These banded rocks are very resistant to erosion and usually form high outcrops. The bodies are mainly moderate to very large, although some are small. Their shape ranges from oval to very elongate, e.g., pegmatite No. 7. (See Plate II).

Sodic plagioclase, microcline, (mainly perthite) anhedral quartz, muscovite and biotite and euhedral to subhedral garnet comprise the general mineralogy (See figures 28 and 29). Anhedral to subhedral tourmaline may be present in very minor amounts in some of these pegmatite bodies. Individual garnet crystals range from 1 to 3 or 4 mm. in diameter. Occasional crystals may attain 12 mm. or more. Dodecahedral and trapezohedral faces are common (Fig. 30).

Texture of the pegmatite is mainly fine to coarse pegmatitic. The variations in texture in this type of pegmatite and the frequency of constituent minerals were at first quite misleading. No zoining, <u>senso stricto</u>, has been noted. Textural variations were first described

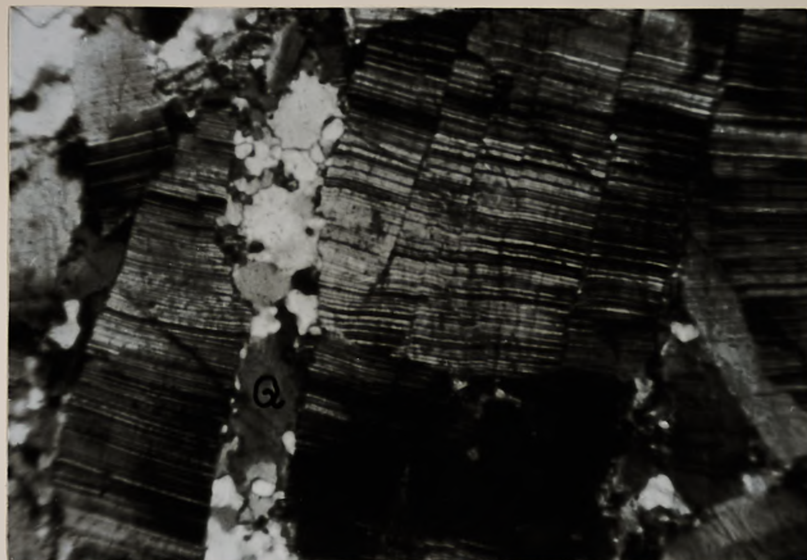


Figure 28. Pegmatite No. 11, albite showing cracks and micro-faults. Cracks filled with later quartz (Q).X-nicols, 80X.

Figure 29. Pegmatite No. 11, Chess-board albite. X-nicols, 80X.

Figure 30. Pegmatite No. 11 showing coarse garnet (G), bent muscovite (M) and cracked albite (A). Very coarse band near the southern end of pegmatite. X-nicols, 80X.

in the field as irregular, and mineralogical variations noted as patchy in character. Recognition of the distribution patterns of the red garnet in these pegmatites finally resolved the true geometric picture of these unusual bodies.

The garnet distribution in the pegmatites is quite remarkable. It is usually concentrated in bands less than 1/2 cm. (about 1/5 in.) in thickness and usually alternates with other bands containing little or no garnet and ranging to 50 mm. (about 2 in.) in thickness. The garnet bands are generally uniform in thickness and may extend over several meters or even tens of meters especially in the small to moderate elongate to very elongate pegmatite bodies (usually of the concordant type, See P.62). In this case the garnet bands are generally parallel to the walls of the enclosing pegmatite bodies and the schist country rock. In the moderate to large oval to elongate (discordant) pegmatites garnet bands may in part parallel the outer schist contacts, but inside such bodies the strike and dip are quite different from those of the schist. Usually these bands fade gradually along their strikes and vary in spacing in a direction perpendicular to the first one, (See figure 31 and 32).

Figure 31. Somewhat contorted garnet-rich, reddish toned bands, discordant pegmatite type, SE$\frac{1}{4}$, sec. 12, T.28N., R.102W., Pen shows scale.

Figure 32. Anderson Ridge pegmatite outcrop, showing oxidation banding "X" and typical garnet banding "G", NE$\frac{1}{4}$, sec.1, T.28N., R.102W.

The garnet-rich bands are much finer in grain size than the other intercalating bands. The texture of these is usually fine to medium, while the other bands may range from medium to coarse. Isolated single fine-grained garnet-rich bands have not been observed in the field. In all cases several such bands occur in a series of alternating garnet-rich and garnet-poor bands. Such a series or unit may alternate with other units that contain minor or no garnet at all (Fig. 33 and 34). The other units may vary considerably in thickness and grain size. Individual bands may extend up to several tens of feet in width. Grain size of these bands is in most cases coarse to very coarse. Within a garnet-rich band the garnet shows mainly rounded grains ranging about 1 to 2 mm. in diameter. It is usually partly altered, especially along internal fractures and cracks, to chlorite, greenish biotite and hematite. Minor tourmaline may sometimes be present. Other main mineralogic constituents beside garnet are sodic plagioclase and quartz. Between individual garnet rich bands and within one and the same garnet-banded series the mineralogical composition remains essentially the same. However, the amount of quartz increases and the texture becomes much coarser. Feldspar usually shows corroded boundaries and is fractured to different extents. The red garnet-rich bands may show contortions and irregularities along their strike. In many

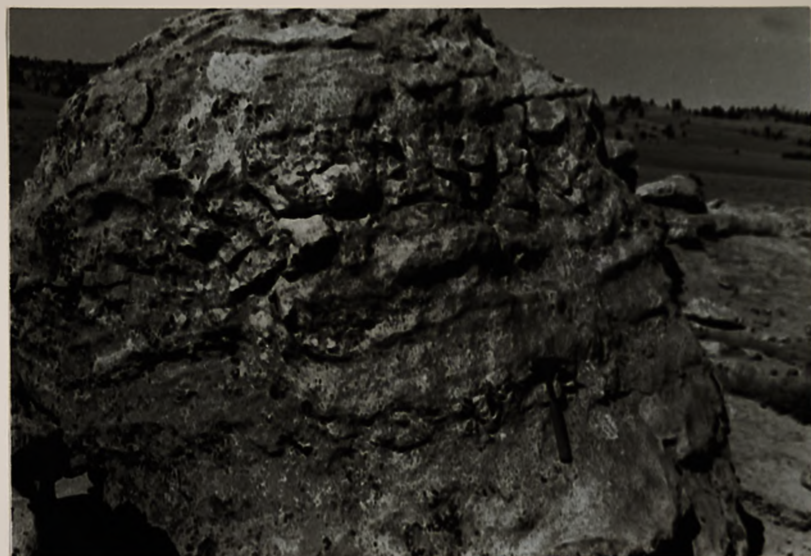


Figure 33. Garnet granite pegmatite showing variation in mineral composition and in texture. Notice weathering characteristics, sec. 34,T.29N., R101W

Figure 34. "Layering" in garnet granite pegmatite (Pegmatite No. 11). Notice both compositional and textural variations, SW$\frac{1}{4}$, sec. 7,T.28N.,R101W.

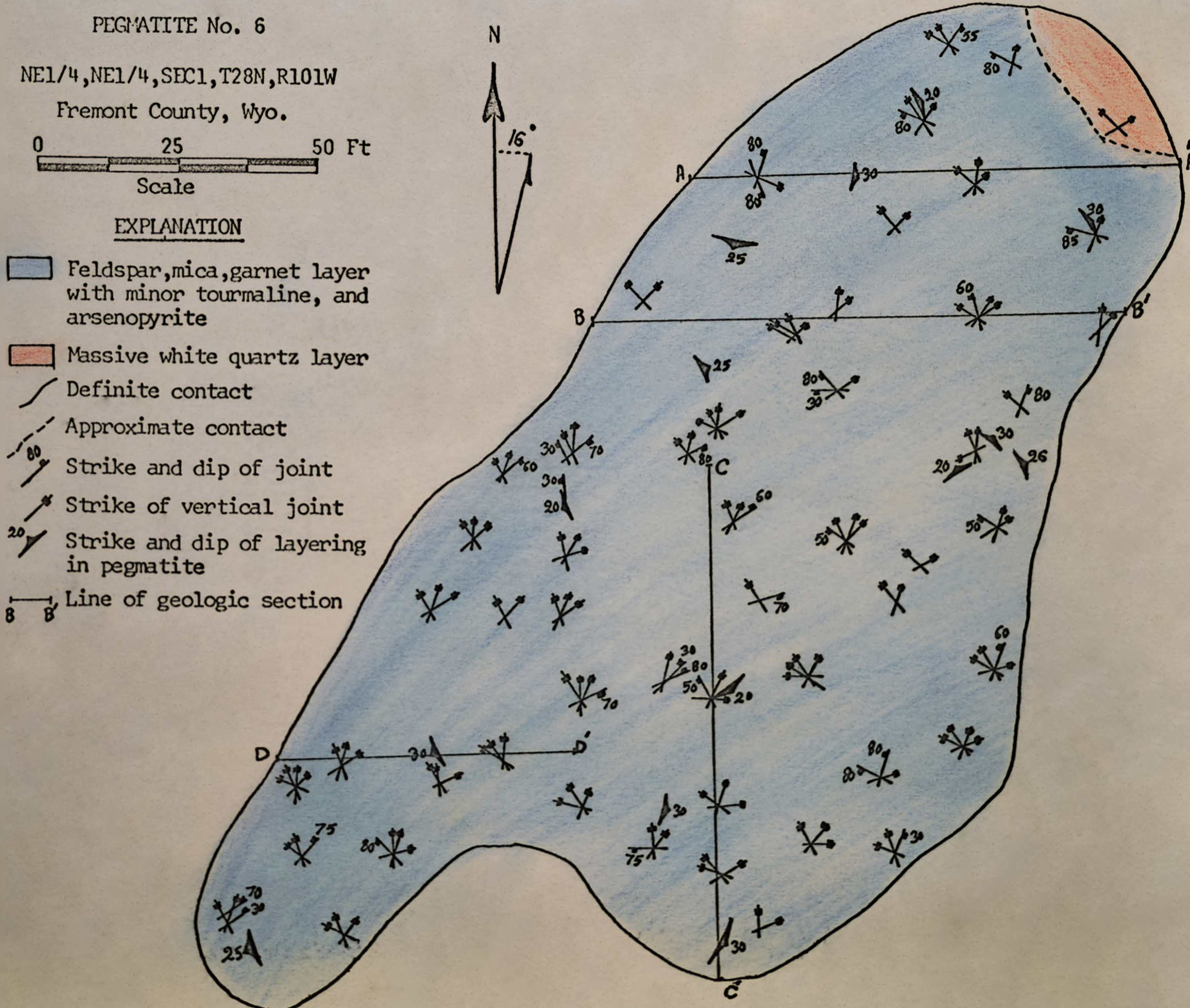
instances the bands show undulations and/or curves bending over and around large feldspar crystals and feldspar intergrowths.

From a geometric viewpoint the pegmatite bodies consist of successive bands of units somewhat analogous in appearance to the layering of a sedimentary rock succession. Zoning, of the type commonly known (e.g., Cameron et al, 1949), has not been noted in the field. Proctor (Personal communication) first noted the banded, layered, and pseudo-folded characteristics of the discordant pegmatites and suggested these were layered pegmatites. Field mapping by the author, Proctor and Johnson confirmed the layered character of these pegmatites.

The garnet-rich bands in a pegmatite may show distinctive attitudes. These can be measured and the direction and inclination plotted to show the internal structures of the body. Good outcrops and marked garnet-rich bands permit a ready interpretation of the internal structures. Results show pseudo-fold characteristics within the pegmatites and a distinct discordance to the wall rock structures. The enclosing country rocks are apparently not deformed by these structures. Details on the internal structures are included in the pegmatite maps and geologic sections discussed later.

In reviewing the literature of pegmatites little has been written about these peculiar layered pegmatites. However, these bodies have been described in the Pala and

Figure 35



PEGMATITE No. 6
NE1/4,NE1/4,SEC1,T28N,R101W
Fremont County, Wyo.
0
25
50 Ft
Scale
EXPLANATION
Feldspar,mica,garnet layer with minor tourmaline, and arsenopyrite
Massive white quartz layer
Definite contact
Approximate contact
Strike and dip of joint
Strike of vertical joint
Strike and dip of layering in pegmatite
Line of geologic section
B
B'
N
16°
A
A'
B
B'
C
C'
D
D'

Figure 36

PEGMATITE No. 6

NE1/4,NE1/4,SEC1,T28N,R102W

Fremont County, Wyo.
Geologic Sections

EXPLANATION

- Anhedral quartz
- Feldspar (lines show relative grain size)
- Mica (mainly muscovite
- Fine garnet-rich bands
- Graphic granite
- Garnet (symbols show relative grain size)
- Tourmaline

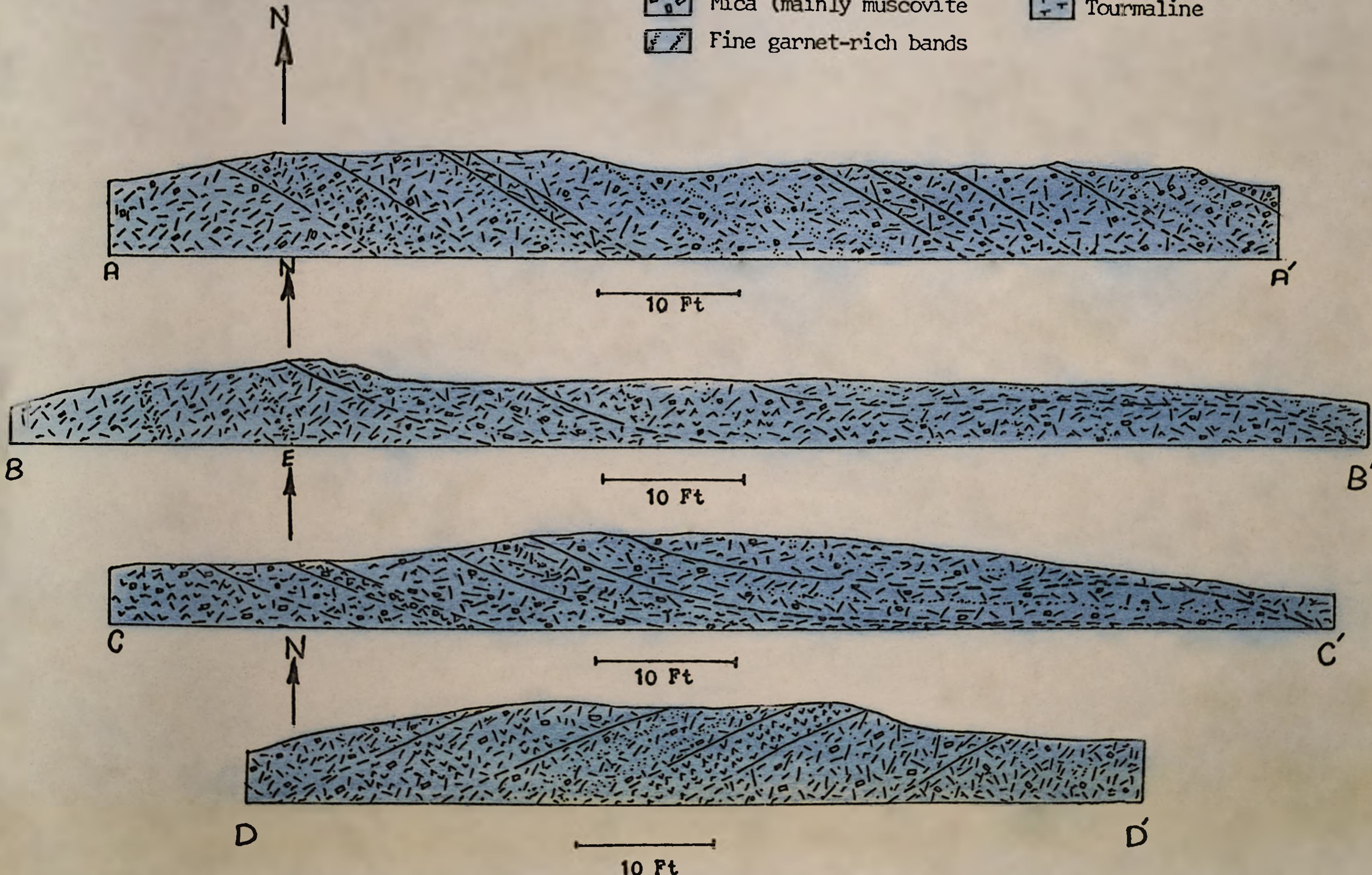


Figure 37

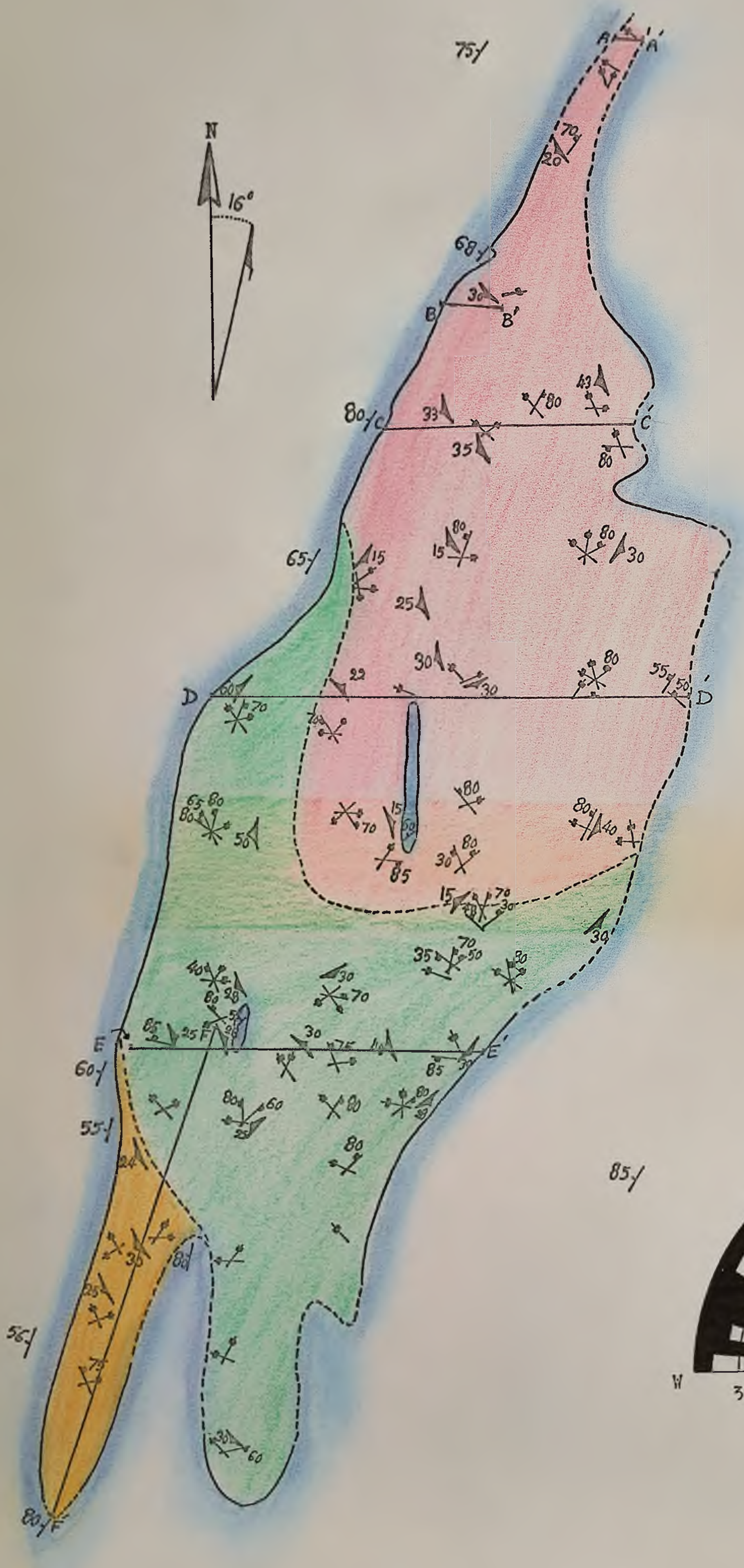
PEGMATITE No. 11

SW1/4,SW1/4,SEC7,T28N,R101W

Fremont County, Wyo.

0 100 200 Ft

Scale



EXPLANATION

- Garnet, muscovite, feldspar layer
- Garnet, mica, smoky quartz, feldspar layer
- Massive white quartz, feldspar layer
- Metamorphic rocks (sericite quartz schist on the eastern side and "peanut" schist on the western)
- Definite contact
- Approximate contact
- Strike and dip of joint
- Strike of vertical joint
- Strike and dip of layering in pegmatite
- Strike and dip of bedding in metamorphic rocks
- Line of geological section

JOINT DISTRIBUTION DIAGRAM

No.'s shown indicate number of joints of certain bearing

Figure 38

PEGMATITE No. 11

SW1/4,SW1/4,SEC7,T28N,R101W

Fremont County, Wyo.

Geologic Sections

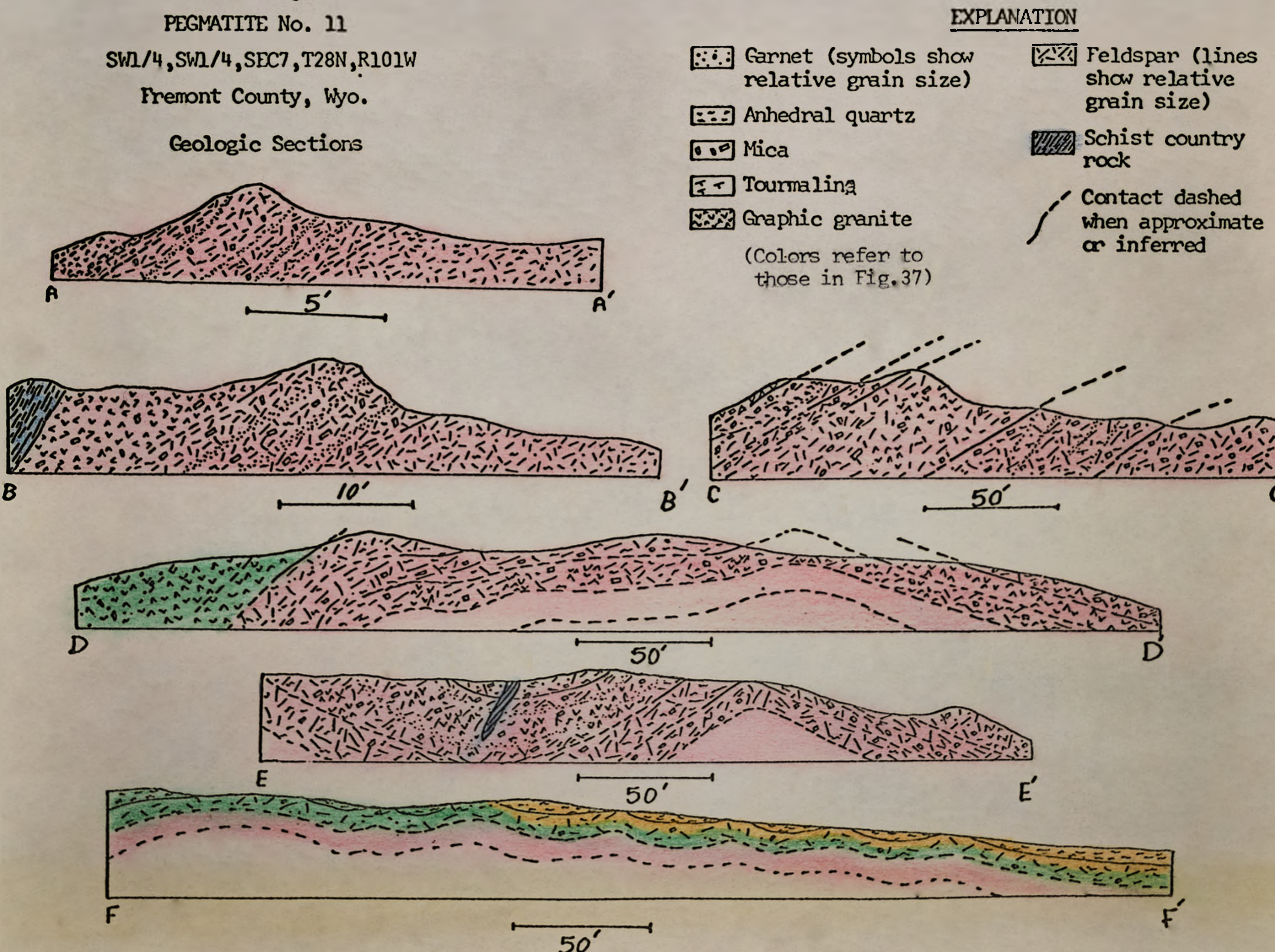


Figure 39

PEGMATITE No. 8

SE1/4,SEC12,T28N,R102W

Fremont County, Wyo.

0 25 50 100 Ft

Scale

EXPLANATION

Banded garnet,mica,feldspar granite pegmatite

Metamorphic country rocks

Contact dashed when partially covered

70 Strike and dip of joint

Strike of vertical joint

70 Strike and dip of layering in pegmatite

65 Strike and dip of bedding in metamorphic rocks

A A' Line of geologic section (picture)

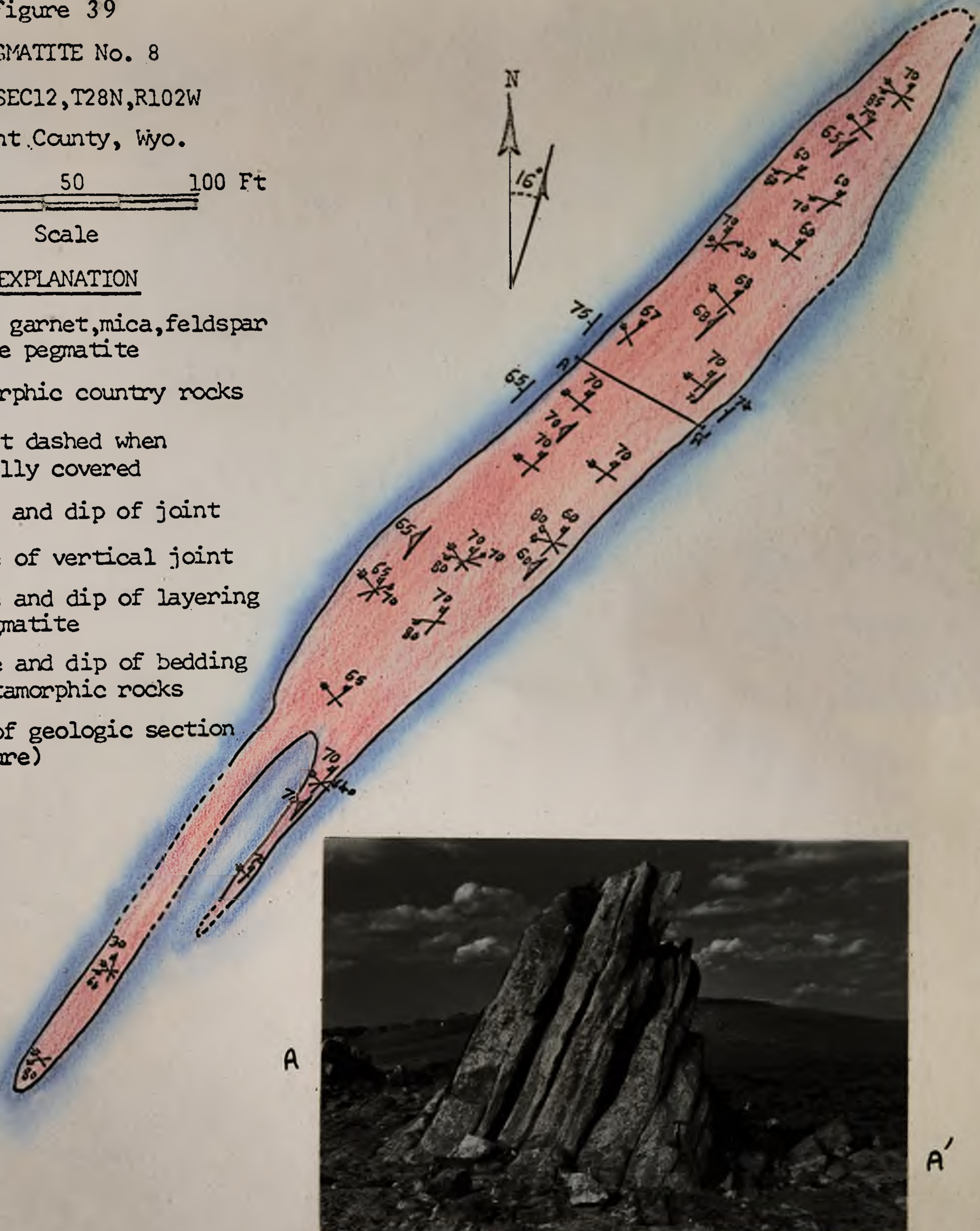


Figure 40

CONCORDANT PEGMATITES Nos. 9 & 10

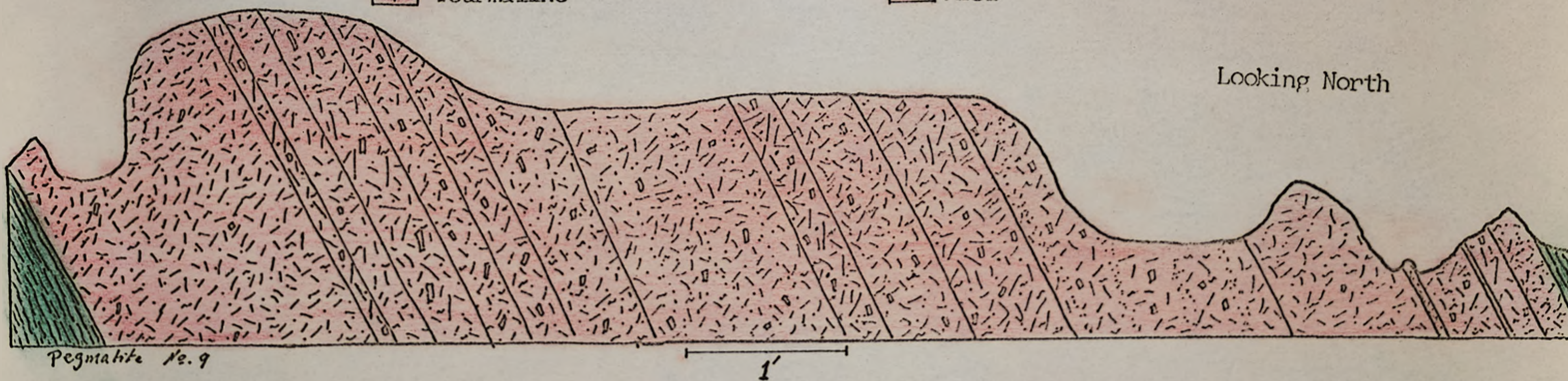
NW1/4,SEC12,T28N,R102W.

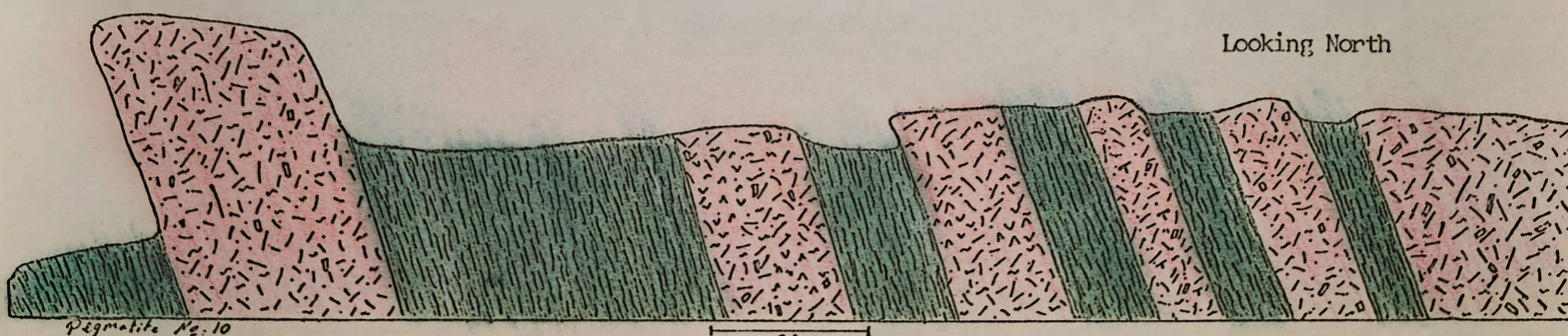
Fremont County, Wyo.

Geologic Cross Sections

EXPLANATION

- Garnet (symbols show relative grain size)
- Anhedral quartz
- Tourmaline
- Graphic Granite
- Feldspar (lines show relative grain size)
- Mica
- Schist country rock
- Contact





Rincon pegmatite areas, San Diego County, California (Schaller, 1925, Jahns and Wright, 1951, Hanley, 1951, and Jahns, 1954), in the Bridger Mountains, Wyoming (McLaughlin, 1940, pp. 62-63), in the Quartz Creek pegmatite district, Gunninson County, Colorado (Staatz and Trites, 1955, pp. 23-24), and in the Dawley Canyon pegmatites, Nevada (Olson and Hinrichs, 1960). Outside the United States these pegmatites are recorded in Canada and the Belgian Congo (in Jahns, 1955, p. 1102). The term "line rock" is frequently used by the above mentioned authors to describe these red-colored fine garnet-banded rocks. The writer prefers to refer to such rocks as "banded" rather than "line rock".

Examples of the layering and "pseudofolds" in this type of pegmatites are shown by pegmatites Nos. 6 and 11 (Figures 35-38). Pegmatites Nos. 8, 9 and 10 are of the same type but show layering parallel to the outer contact (Figures 39 and 40). Structurally the former two pegmatites are of the discordant type while the latter are concordant.

5. Biotite granite pegmatites

The biotite granite pegmatites lie to the south of the tourmaline-bearing granite pegmatite zone and are especially well represented in sections 19 and 20, T.28N., R.101W. These bodies are resistant to weathering and erosion and form readily visible outcrops. They are leastt affected by joints and shear fractures. The granite pegmatites are concordant with the enclosing schist. Size of the bodies is small to moderate. Shape varies from elongate to very elongate. These pegmatites show pinch and swell structure especially in the central part of the section line between the above mentioned two sections. This structure clearly resembles and probably represents boudinage structure resulting from the actual stretching of the pegmatite during deformation of the country rock. Texture is generally fine to medium. Mineralogical composition is mainly sodic plagioclase and anhedral quartz. Garnet is almost absent and mica is not very abundant and is mainly of the brownish variety (biotite).

B. Structural Types of Pegmatites

Pegmatites in the Anderson Ridge quadrangle can be grouped into three main types on the basis of their relationships to the country rocks:

1. Concordant pegmatites in schists
2. Discordant pegmatites in schists
3. "Fracture-fill" pegmatites in granites

1. Concordant Pegmatites in Schists

Concordant pegmatites parallel the strike and dip of the enclosing schist country rocks. They generally follow the direction of bedding rather than the foliation direction. However, it must be noted that in the southern half of the area the bedding and the foliation directions are generally coincident. Usually the concordant pegmatites are small to moderate in size but sometimes large. Shape is usually elongate to very elongate.

The concordant pegmatites, in most cases, show a central layered zone of minerals much coarser than the marginal material and rich in pure massive anhedral quartz. However, zoning in the restricted sense may or may not be present. Instead banding or "layering", without repetition on both sides of the pegmatite bodies, is much more common. This banding may be due to textural and/or compositional variations. Different mineralogical types of pegmatites are represented in this group including types 3, 4 and 5 mentioned above.

In all cases, the country rock schist-pegmatite contact is well defined and sharply marked in the field (Fig. 41). No gradational or transitional zones have been observed. However, medium-grained muscovite (paragonite, D. Hodge, personal communication, 1963), medium- to coarse-grained prismatic hornblende or fine-grained tourmaline may develop along the contacts. A contact zone a few millimeters in width having characteristics of a chilled zone is present in many of these pegmatite bodies.

Schist inclusions are common in this type of pegmatite. These inclusions are of minor size compared to the size of the pegmatites. The included schist parallels the main direction of elongation of the pegmatite body and, of course,

Figure 41. Garnet granite pegmatite (pegmatite No. 7), concordant type. Notice low-lying outcrop and sharp outer contact.

Figure 42. Pegmatite No. 7, Schist inclusion parallel elongation of the pegmatite and its contact with the wall rock.

parallels the strike of the enclosing schist (Fig. 42). However, the concordant pegmatites may be intercalated with schist bands of comparable size or even larger. This interlayering of schist and pegmatite material increases until the schist is dominant or vice versa and a large pegmatite of the concordant type usually results. The schist inclusions in all noted cases are invariably mica and/or chlorite-quartz schist but never of the garnet- or "peanut"-type. Fine-grained chilled contacts are usually present where the pegmatite material is in contact with the schist inclusions or at the outer schist contacts.

2. Discordant Pegmatites in Schists

Discordant pegmatites do not coincide with the strike and dip of the enclosing schist. They may cut across or even be perpendicular to the strike of the schist (Fig. 43 and 44). In many cases these pegmatites parallel the strike of the schist on the surface but differ in the amount of dip.

By far, the largest and most important bodies of this group are arranged in a zone trending northeastward in sections 21, 28, 29, and 32, T.29N.,R.101W., sections 6 and 7, T.28N.R.101W., and sections 1 and 12, T.28N.,R.102W.

Pegmatite bodies of this group vary greatly in size ranging from small to very large. Shape is quite variable and more irregular than any other group. Generally it ranges from oval to elongate and sometimes rounded. Texture range

Figure 43. Discordant garnet granite pegmatite, SW¼, sec. 12, T.28N., R102W. Sericite-quartz schist country rock, strikes N 43E and dip 74 NW, Pegmatite, strike N 60 W and plunges 32SW (Geol. Section A-A' shown below)

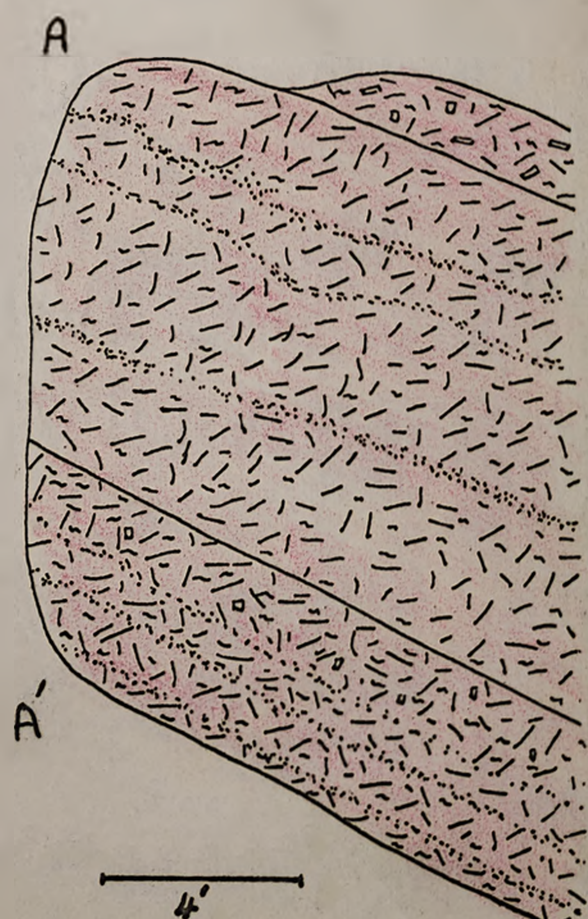


FIGURE 44.

Detail of section

A - A' above

- Fine garnet-rich band
- Quartz
- Mica (muscovite in top band and biotite in the lower)
- Perthite

from fine to very coarse. The textural variations apply for different pegmatites of the group as well as the different bands of one and the same body.

Mineralogically speaking, the discordant pegmatites are mainly garnet bearing with or without minor tourmaline and are almost grouped in mineralogical type 4 noted above. The relative frequencies of constituent minerals is noticeably different in the different bodies.

Internal structural studies of the layering of these pegmatites indicate that they do not accord with the structure of the schist country rock. Pseudo-folds and warping of the layering are very common in these bodies. The schist in all noted cases is not structurally affected by the internal features of the pegmatites.

Pseudo-fold is used to describe the wave-like character of the discordant pegmatites as revealed by both the external outcrop pattern and the internal layering. Schists above and below these pegmatites do not show any such related characteristics. Work on the regional distribution pattern of the pegmatites in the quadrangle and on the internal structures by the author and Professor Proctor indicate that the pseudo-fold structure of the pegmatites has a general northerly trend. The plunge of the pseudo-folds in the large controled pegmatite body of section 28 (NW$\frac{1}{4}$), T.29N.,R101W. is generally north-northeast. Pegmatites of this group further to the south generally plunge south to southwestward.

The plunge is usually gentle but sometimes up to 30° (Fig. 43). Smaller pseudo-folds within individual pegmatites have the same general plunge direction but they may deviate from this direction because of local contortions.

Across the general plunge of the pegmatites one recognizes a succession of mineralogical bands of varying texture and mineralogy (fig. 36). These bands or layers range from a few millimeters to several meters in thickness. Contacts between the different bands are usually distinct and marked by a change in texture and/or mineral composition. No constant mineralogical or textural sequence was noted in the field from the lower to the topmost layers.

3. Fracture-fill pegmatites in granites

Pegmatites in the northern granite terrane are quite distinctive from those in the schists. Because of the lack of well-defined structural criteria they are lumped in one group. In cases where foliation directions are recognizable in the granite, classification into concordant and discordant types is possible. It was found in such conditions that some pegmatites are concordant with the foliation direction but most of them are discordant. Sometimes these discordant pegmatites follow the foliation direction on the surface but in the third dimension they usually show a smaller angle of dip than that of the granite foliation.

Pegmatites in the granitic country rocks are small to moderate in size and oval to elongate in shape but sometimes are rounded. Texture is fine to medium and is invariably even grained (equigranular) although in cases porphyritic.

Contact relation between the pegmatites and the granite country rock is in all cases sharp and clear cut. Branching of the pegmatites is not uncommon (fig. 45). In one case a small pegmatite vein cuts and slightly dislocates, about 1 foot, another similar dike (fig. 46).

Figure 45. Branching pegmatite cutting through Sweetwater granite, looking west, sec.3, T.28N., R.102W.

Figure 46. Two generations of pegmatites, one cuts the other, Sweetwater granite stock, sec. 3,T.28N.,R102W.

IV. ORIGIN, GENESIS AND AGE OF PEGMATITES

A. General Statement

Various theories introduced to explain the origin of pegmatites may be classified into 3 main groups (Landes, 1933, Jahns, 1955).

1. Aqueous theories: includes lateral secretion and selective solution.
2. Igneous theories: includes segregated or injected magma, segregated or injected highly fluid magma, injected magma formed by anatexis or palingenesis and aqueous solutions derived from magma.
3. Metamorphic theories: includes recrystallization, anatexis or palingenesis, replacement or secretion by non-magmatic fluids, and replacement or secretion through particle diffusion (metamorphic differentiation).

1. Aqueous theories

a. Lateral secretion theory

According to the lateral secretion theory the source of elements in a pegmatite body is the surrounding rock and the groundwater is the medium of solution and reprecipitation.

This theory was popular during the nineteenth century but is now largely discarded as inapplicable to pegmatites.

b. Selective solution theory:

The selective solution theory explains the development of the constituent minerals of the pegmatites as a result of selective solution and reprecipitation of given mineral constituents from the original country rock. This takes place in the presence of interstitial water and with increase in temperature and pressure. The resulting rock is igneous in appearance and pegmatitic in character. The theory emphasizes "given" bands or layers in the country rock that are more favorable and susceptible to solution than the others. The theory was introduced to explain the lit-par-lit (concordant) pegmatites.

2. Igneous theories:

The derivation of pegmatites from an igneous magmatic origin has been emphasized since the nineteenth century. Concensus of opinion at present is generally in favor of this theory although different investigators may not agree as to the character of the parent magma. Some attribute the pegmatites as formed from a magma characterized by viscous liquids or gels. Others favor precipitation or crystallization of the pegmatite bodies from an attenuated residual granitic magma.

The presence of volatiles in the parent pegmatitic magma is exceedingly important, but here again different writers vary greatly as to whether crystallization took place in a closed, semi-closed or an open system and also whether volatiles are present at all times or partially during given phases of the pegmatites crystallization. Landes (1933, p.53) describes the "pegmatitic magma" as "...more aqueous than the original magma, but it does not approach the degree of attenuation of hydrothermal solutions. It crystallizes in a manner similar to that of an ordinary body of magma but because of its content of volatile materials the freezing point is lower and coarser crystals will form."

3. Metamorphic theories:

The metamorphic theories mainly involve recrystallization or transfer of material by diffusion or by non-magmatic fluids, with development of pegmatite masses by metasomatism, porphyroblasis or open-space filling.

Although the metamorphic origin of pegmatites may explain some observed field relations in a few cases, yet these theories, senso latus, are inapplicable to the problem of origin of the pegmatites.

B. Genetic problems of Pegmatites in The Anderson Ridge Quadrangle

The problem of the pegmatites in the Anderson Ridge area are far from solved completely. However, a preliminary discussion of the variations in spatial distribution and genetic relationships with the different country rocks seems appropriate.

Genetically speaking, there is no difference between the concordant and discordant pegmatites. Field evidences indicate that there is every graduation between the thin interbedded concordant pegmatites and the large discordant types.

The theory of selective solution as applied to the lit-par-lit (concordant) pegmatites, as mentioned above, can hardly apply for this group in the area under discussion. Against selective solutions are the following criteria:

1. In one and the same mineralogic pegmatite group, e.g., the garnet granite pegmatites, there are both concordant as well as discordant representatives, i.e., Some parallel lithologic units others may cut across units of varying chemical composition.

2. Some concordant pegmatites as well as discordant ones contain minerals of a composition not able to be provided by the schist country rock in the amounts necessary for their formation e.g., beryl, arsenopyrite, rare earth minerals, etc.

3. Field study shows that there is no evidence of "given" layers or bands in the shist country rock that are much favorable to selective solution than others. Schist inclusions within pegmatites are usually of one and the same type as the enclosing rock.

4. The pegmatite bodies themselves show no change in the mineralogical composition or internal structure that can be correlated with differences in the country rock composition. Also, the internal structure of these bodies does not reflect the detailed structure of the country rock as for example in the case of the layered garnet-banded granite pegmatites.

The concordant pegmatites appear to have crystallized from the walls inward. Sometimes zoning, senso stricto, may be present and the central core is usually coarser in grain size and simpler in mineralogical composition. However, in many other cases the variation in texture and/or composition is much better explained in terms of "layering" or banding than zoning. In still other cases the texture as well as the composition remain the same throughout the width of the pegmatite body.

In case of discordant pegmatites it is difficult to ascertain whether crystallization starts from the walls inward or vice versa. But based on field observation, it seems that "eddies" and swirls, whether in a highly viscous or highly fluid pegmatitic magma, are common especially during the crystallization of the garnet-banded rock. The crystallization of the discordant pegmatites is by no means simple or uniform.

All the pegmatites in the Anderson Ridge area are believed to be of igneous origin. Evidence of forceful intrusions of these bodies is in almost all cases absent. The attitude of the enclosing rock does not change in the near vicinity of the emplaced pegmatite bodies. The general opinion is that the pegmatites have been formed by injection of relatively fluid magmatic material along fractures or other planes of weakness in the host rocks and, in many cases accompanied by assimilation of older rocks. In the case of concordant pegmatites magmatic material follows the main weakness planes of the country rock, widening these fractures and in part replaces the original rock. Discordant pegmatites have the same mechanism. Apparently an excess of the pegmatitic fluids permitted an encroachment on and assimilation of the host rock to a larger extent.

Country rock inclusions are common in the different pegmatite masses and in many cases show different degrees of assimilation by the magmatic solutions (see fig. 47). The pegmatite-country rock contact, both in the metamorphic and granite terrane, is usually sharp and clean cut in the field. Microscopic study of the contact relations shows that, except for some local development of hornblende, tourmaline and secondary crystallized muscovite (paragonite), there is quite a distinct difference in the mineralogic composition. The directions of schistosity are in most cases not disturbed.

The "peanut" problem:

The "peanuts" in the schists may bear on the genesis of the pegmatites and the transfer of material from and into the host rock. Preliminary study of these materials show that some of them are highly altered aggregates of sillimanite and muscovite. These minerals seem to be developed after andalusite. But, of importance is the other group of "peanuts". These have been found to consist mainly of recrystallized sodic plagioclase and microcline, the latter in

Figure 47. Remnants of schist (R) in garnet granite pegmatite, sec. 12,T28N, R102W.

many cases being perthitic. Poikilitic texture is characteristic and enclosed inclusions are mainly biotite, quartz, and small feldspar grains predominant in the host rock. Schistosity directions around these "porphyroblasts" are usually disturbed.

Higazy (1949) in his study of the pegmatites of the Black Hills, South Dakota refers to a similar type of peanuts or "metacrysts". He states that (op. cit., pp 557-8) "The perthite (metacrysts) of the schist appears mainly along the schistosity as small ovoid masses less than 1 mm. in diameter grading into masses more than 3 cm. long, which tend to assume the rectangular outlines of a true feldspar. Some of the larger metacrysts have biotite lamillae curved around them, indicating that the growing feldspar crowed aside the folia of the schist. The ovoid masses sometimes join and form a pinch and swell structure...". Pinch and swell structure has not been found in the way described above. Of interest is Higazy's genetic interpretation of these perthite inclusions. He mentioned that "replacement rather than viscous intrusions and magmatic crystallization seems to be best explanation of these phenomena..." and lastly he postulates a metamorphic origin for those pegmatites.

Jahns (1955, p. 1092) criticizes this theory in some detail emphasizing the significant differences between the composition of the perthites and the bulk composition of the pegmatite bodies and that the theory fails to account for the concentrations in the pegmatites of elements such as beryllium, lithium, and phosphorus.

While Higazy's theory cannot explain the origin of the Anderson Ridge pegmatites in the metamorphic country rocks, the writer believes that the feldspathic peanuts in that area may be the result of a process of feldspathization of the schists by pegmatitic solutions. Further work is needed.

C. Origin and Space Relationships of Individual Pegmatite Types in Area.

1. Magnetite granite pegmatites

Magnetite granite pegmatites are related to aplite dikes especially in the eastern part of the northern batholith. The mineralogical content indicates an original crystallization from a liquid magma not rich in volatiles. The composition of the original fluid was apparently very near to a granitic magma. The temperature was so high that characteristic low-temperature volatile-rich pegmatite constituents were not deposited, and only the relatively high-temperature mineral magnetite crystallized in addition to the granitic minerals.

The associated aplite dikes are believed to have formed under similar conditions, but at a later stage when most of the volatile constituents had escaped from the system.

Magnetite crystallized later than the essential silicate minerals. It is usually anhedral and fill the interstices of the essential minerals.

The relation between the magnetite pegmatites and the other types of pegmatites in the mapped area is uncertain. They are distinctively magnetite-bearing. They do not appear to be related to the graphic granite pegmatites in the northwest granite stock area. However, the magnetite-bearing pegmatites are evidently directly related to the northern batholith and represent a late phase in its crystallization evolution.

2. Graphic granite pegmatites

The graphic granite pegmatites are mainly located in the northwestern sill-like granite body. However, some occur outside this body, in an aureole extending east to section 19,T .29N, R.101W., associated with other types of pegmatites. Graphic granite bands or masses are present, at least in part, in the main pegmatite groups of the area; mainly the garnet-bearing, and tourmaline-garnet-bearing granite varieties and usually represent distinctive very coarse grained bands.

Opinions differ greatly (Jahns, 1955) on the origin of graphic granite pegmatite. Some investigators suggest simultaneous crystallization of feldspar and quartz in an eutectic type of reaction. Main objection to this mode of origin is the large variation in the quartz/feldspar ratio as determined quantitatively. Other researchers, on a petrographic basis, found that the quartz blebs are rarely interconnected and emphasized the consistency of their crystallographic orientation with respect to that of the host feldspar. These types of orientations are widely recognized. Others believe in the development of these quartz-feldspar intergrowths by hydrothermal replacement of solid feldspar crystals. Wahlstrom (1939) reviewed the problem and concluded that the existence of quartz in crystallographic orientation in graphic granites is the exception rather than the rule. He found that quartz in most of the graphic granite formed by replacement processes, and that simultaneous crystallization accounted for some occurrences.

The writer's opinion is that graphic granite is produced mainly by direct crystallization from a magma. Replacement may be important in a very few cases. The discontinuity of the quartz blebs shown by both field and microscopic study does not favor an origin by replacement.

The relation between the magnetite-bearing pegmatites in the main northern granite and the graphic granite pegmatites in the northwest granite body is not exactly known. If the origin of the stock is the same as the northern batholith and the former represents an outlier, the graphic pegmatites may represent another mineralogical phase in the evolution of the batholith other than the magnetite-bearing phase. Whether the graphic granite pegmatites are contemporaneous with, supersede or precede the magnetite granite pegmatites is not certain. Absolute age dating would be of great help in solving this as well as other problems in the area.

Field study of graphic granite, partially present in bands within other pegmatite groups, reveals almost the same structure and composition as the main graphic granite pegmatites noted. Apparently both crystallized under similar conditions. The graphic granite in the former case appears to have crystallized at depth and was then carried as a solid in the rest magma upward. The erosional appearance of this rock material (See fig. 33) and the microscopic study of the feldspars supports this concept. In most cases feldspar crystals show marked bending, fracturing and even microfaulting.

3. Tourmaline granite pegmatites

The tourmaline granite pegmatite group is divided into 3 subgroups. Although each of them contains the same type of tourmaline both their overall mineralogical composition and texture varies greatly. Apparently each type crystallized under a given set of physico-chemical conditions and a different concentration of the constituent minerals. The first subgroup is characterized by an abundance of volatiles and concentration of very large crystals of important pegmatitic minerals. The second subgroup has a relatively simple mineralogy and much finer grain size. The third subgroup is characteristically rich in fine-grained garnet.

a. Very coarse tourmaline-beryl-granite pegmatites

The very coarse grained pegmatites crystallized from a pegmatitic magma under conditions which promoted the development of very coarse pegmatitic texture. It must have been rich in volatiles and hyperfusible constituents and probably had relatively low viscosity. Crystallization probably took place under a restricted or closed system where confining pressures were sufficiently great to prevent major escape of the volatile constituents. The mineralogical composition of the magma is more or less like those of the other tourmaline-bearing subgroups except the garnets in this case are distinctively large, patchy in distribution and usually present in minor amounts.

b. Medium to fine spotted tourmaline granite pegmatites.

This second subgroup is of local distribution and is directly related to the other tourmaline-bearing pegmatites. However, they do represent a different phase in the pegmatite crystallization characterized by a garnet-poor pegmatitic fluid. Crystallization did not take place in a completely closed system. Most of the volatiles escaped resulting in less coarse pegmatite texture and a mineral assooiation with no abundant volatile-rich constituents.

c. Medium to fine grained tourmaline-garnet-granite pegmatites.

This third subgroup has the same origin as the garnet granite group to be discussed next. Actually it is very hard to draw the boundary between these two groups. They are almost the same in character except that one group contains conspicuous tourmaline.

4. Garnet granite pegmatites

The garnet granite bodies crystallized under diverse conditions of temperature and pressure as well as different concentrations of volatiles and hyperfusible constituents. Different phases of crystallization were characterized by sudden and/or gradational variation in mineral composition. The coarse grained bands are essentially composed of potash feldspar. This in most cases is perthitic and/or with graphic intergrowths. These constituents seem to crystallize from pegmatitic magma first. The fine garnet-banded rock which usually alternate with the noted potash feldspar-rich bands shows undulation, curves, and warps around such masses of coarse feldspar and graphic granite. These constituents could have been carried to their present position in a partly solid state. The magmatic solution was also partly solid when the fine garnet bands started to crystallize.

Because of the banded character of the large perthitic feldspar zones in the pegmatites, the other possibility suggested is crystallization, in situ, and large growth of the feldspars. The fluids would have to have been enriched in potash containing more volatiles to decrease viscosity, and had time to develop these large masses before the next band formed. This also suggests multiple injection of the pegmatite forming fluids.

During the crystallization of these banded rocks the pegmatitic magma was at least in part liquid and allowed a plastic-type of movement and adjustment or detachment of the coarse grained blocks from already completely crystallized masses before the complete solidification of the pegmatite. Repetition of garnet-rich layers or bands may indicate a change in the pegmatitic fluid caused by addition of new material from below, by loss of material to the walls, or failure of concentration to maintain equilibrium throughout the fluid.

In the garnet-and tourmaline-garnet-bearing pegmatites occasionally some layers or bands of pure massive quartz are present. These vary from white milky quartz to very dark smokey varieties. In some concordant pegmatites the massive quartz may occur in the central zone (core) of the pegmatite. The origin of this quartz is as yet an unsolved problem. Jahns (1955, p. 1094) commented that, "a quartz core would be the normal end product in crystallization of a pegmatitic liquid undergoing resurgent boiling. The alkalies in such a system would be progressively removed in the vapor phase, whereby silica would be progressively enriched in the liquid phase perhaps to very low temperatures".

The writer agrees with this explanation and extends it to the pure quartz layers and suggests that the above mentioned cconditions were repeated more than once in the complex history of crystallization of the layered pegmatites.

The garnet-and tourmaline- garnet- granite pegmatites in the Anderson Ridge area are related in composition and texture to the eastern garnet granite stock. It is believed that both have one and the same source. The spatial distribution of these pegmatites in the central part of the quadrangle and the presence of the largest bodies there may indicate a buried stock at depth connected with the eastern one.

5. Biotite Granite pegmatites

These granite pegmatites are mineralogically simple and may represent the oldest pegmatites in the area. They show a pinch and swell structure which means, if true, that the pegmatites have been stretched and plastically deformed during the deformation of the country rocks. Further field study is needed to prove whether these structures are true boudinage structures or a lens-like development of pegmatites.

Absolute age dating may be of help in solving this problem. Apparently this group of pegmatites is not directly related to the main garnet-bearing pegmatites mentioned above and genetically represents a group by itself.

V. ECONOMIC POTENTIAL OF THE ANDERSON RIDGE QUADRANGLE

A. General Statement

To date the most important economic mineral in the pegmatites of the Anderson Ridge area is beryl. Recently initiated prospecting is directed for this mineral. The pegmatites examined are of relatively simple mineralogy. They show no distinctive replacement phenomena. This reduces the possibility of finding important replacement-type economic minerals. Vugs, pockets, and cavities are also absent. The chance of finding valuable cavity-filling, well-developed crystals appear remote.

The tourmaline found in these pegmatites is invariably of the black schorlite type. No gem varieties are known.

Columbite was found in Pegmatite No. 5 in very minor amounts. The small quanity and its sporadic occurences within the pegmatites indicate that it is of little economic importance.

Minor arsenopyrite was noted in Pegmatite No. 6.

B. Potential of the different pegmatite types

1. Magnetite granite pegmatites

The magnetite granite pegmatites are of insignificant economic importance. The low content of magnetite is usually scattered throughout the pegmatite bodies and represents about 1 to 4% by volume. It definitely cannot be considered as even a low grade iron ore.

The aplite dikes related to these magnetite-bearing pegmatites are not very abundant and are of relatively small size. They, too, have no known value.

2. Graphic granite pegmatites

Some of the graphic granite pegmatites may have economic value as a source of feldspar. These bodies are very coarse and of good quality. Unfortunately the lack of nearby market mitigates against them. Commercial feldspar is used chiefly as an ingredient for glasses, pottery, and other ceramic products (Jahns and Wright, 1951, p. 46-47). It is also used as an abrasive, building material and grinding agent. It is usually ground to various mesh sizes so as to fulfill the requirements of the different branches of the ceramic industry. Feldspar is usually graded on the basis of its freedom from iron and its content of free silica. Small quantities of admixed quartz commonly are accepted for most cases of ground feldspar, but iron has to be very low in all grades. Biotite, garnet, and other iron-bearing impurities impart an objectionable discoloration to most ceramic products in which the feldspar is used. The graphic granite pegmatites contain hardly any mafic iron-bearing mineral.

3. Tourmaline granite pegmatites

The tourmaline granite pegmatites are the most important type of pegmatites in the Anderson Ridge quadrangle since they are the source of beryl, scrap mica, and relatively pure feldspar. The very coarse tourmaline-bearing granite pegmatites are the most favorable host for beryl, e.g., Pegmatites Nos. 2 and 3. Development work is underway on these bodies. A spectrographic analysis of a beryl crystal from Pegmatite No. 2 shows Be, Al, and Si as the main constituents, Mg, Mn, Fe, Ti, K, B, and Sn as the trace elements.

Although Pegmatites Nos. 4 and 12 are of the same character as Pegmatites Nos. 2 and 3, they have not yet produced beryl. The patchy distribution of beryl in these bodies suggests that further development work will be necessary to evaluate them.

Feldspar (mainly of the perthite variety) is very abundant in these pegmatites. It is coarse-grained and of good refractory character (Fig. 48).

Pegmatite No. 12 produced several tons of scrap muscovite during the summer of 1962 (See figures 49 & 50).

4. Garnet granite pegmatites

Garnet granite pegmatites and tourmaline garnet granite pegmatites (mineralogic type 4 and 2-b-ii respectively) may prove to be another source of beryllium minerals especially in the coarse perthitic bands and those of massive quartz. According to J. Wentz (personal communication, 1962) this massive quartz may contain up to 12% beryllium oxide. Similar beryllium-bearing massive quartz was shipped and marketed at Caster, South Dakota by Mr. Wentz in Summer, 1962.

Figure 48. Tourmaline pit (Pegmatite No. 4), showing feldspar (F) and quartz (Q). Note size of feldspar masses.

Figure 49. Mica pit (Pegmatite No. 12), Hand-cobbing of muscovite "books".

Figure 50. Mica pit (Pegmatite No. 12), Mechanical shoveling of waste rock.

5. Biotite granite pegmatites

Because of the presence of biotite, feldspar industry specifications in regard to iron content may be exceeded. This would eliminate these bodies from consideration as probable sources of feldspar.

C. Beryllium Test

Thirty samples were analyzed for their beryllium content using the method described by Dressel and Ritchey (1960). The test is satisfactory but the fluorescence is usually very weak. However, a traceable change in the color of the quinizarin dye from blue to lilac occurs when beryllium is present before using the ultra violet light. The test could be stopped at this step since in many cases the use of the ultra violet light adds nothing to the eye-observed change in color. In the field (Wentz, personal communication, 1962) a filter paper is used to place a drop of the neutral dye (i.e., without any beryllium content) and match its color with those of the beryllium-bearing samples. In this case quinalizarin is used as a reagent and no ultraviolet light is needed. A thorough evaluation of the various pegmatites has not yet been made.

D. Geophysical work

Some magnetic traverses were run over two selected pegmatites and their adjacent country rocks. The variations in magnetic susceptibility of these rocks are insignificant. (A. Saad, personal communication, 1962). For most pegmatites the magnetic method does not appear to be satisfactory for outlining them or predicting their size in depth.

Scintillator traverses for possible radioactivity in the pegmatites gave no encouragement in the few pegmatites tested. Further systematic geophysical work is needed before a final decision on the pegmatites of the district can be made in regard to the mineral groups amenable to these exploration techniques.

CONCLUSIONS

A brief description of the general geology of the Anderson Ridge quadrangle is presented and a general geologic map included. These data are from Professors Proctor and Johnson and the work of the author. The distribution of the pegmatites and their general types were mapped in the field by the author and Professor Proctor and a compiled map of the pegmatite occurrences completed. Various detailed geologic maps and cross sections of individual pegmatites were prepared by the writer using a Brunton compass and tape. Investigation of the mineralogy was carried out in the laboratories of the Missouri School of Mines and Metallurgy. Further work is needed on the spatial distribution of the various pegmatite types and much more detailed sampling and mapping of the geometric pattern of the "layered" pegmatites. The overall investigation has resulted in some significant contributions.

General age relationships of the different rock units have been established. From oldest to youngest these are for the Pre-Cambrian units:

1. Metamorphic schists
2. Batholithic granite
3. Granitic stocks
4. Pegmatites
5. Basic dikes and sills and a much younger group of Tertiary sediments.

Because of the large number of pegmatites in the Anderson Ridge district and their varied sizes and shapes a geometric classification has been jointly developed to statistically describe them. Length X with (LXW) value of any regularly-shaped individual pegmatite is used as a parameter for size. Pegmatites with LXW values of 2000 $ft.^2$ or less, between 2000 and 20,000 $ft.^2$ or more than 20,000 $ft.^2$ are defined as small, moderate, or large respectively. The length/width (L/W) ratio describes the shape of any pegmatite. Pegmatite bodies with L/W ratios of 1-2, 2-5, 5-10, and more than 10 are defined as rounded or square, oval or rectangular, elongate, and very elongate respectively. In case of branched or irregular pegmatites it is possible to subdivide individual bodies into more or less geometric units. The average length X average width value and the composite length/composite width of the different units can be used as parameters. Realizing the very large variations of texture in pegmatites a new classification of texture based on a ~~logarithmic~~ geometric scale is proposed by the author. The terms very coarse, coarse, medium, fine and very fine refer to grain sizes more than 256 mm., between 256mm. and 16 mm., between 16 mm. and 1 mm., between 1 mm. and 1/16 mm., and less than 1/16 mm. respectively.

Five distinct mineralogic types of pegmatites have been recognized in the area. These include:

1. Magnetite granite pegmatites

2. Graphic granite pegmatites

3. Tourmaline granite pegmatites

4. Garnet granite pegmatites

5. Biotite granite pegmatites

Both concordant and discordant structural types of pegmatites are present. These include different members of the above mentioned mineralogic groups.

Type (3) is subdivided according to texture and presence of distinctive minerals other than tourmaline into:

a. Very coarse tourmaline beryl granite pegmatites

b. Medium to fine tourmaline granite pegmatites

    i. Spotted tourmaline granite pegmatites

    ii. Tourmaline garnet granite pegmatites

Garnet granite pegmatites (Type 4) as well as tourmaline garnet granite pegmatites (type 3-b-ii) are characterized by fine-grained red garnet-rich bands. Attitude of these bands have proved useful in determining the internal structure of the pegmatites. These garnet bands are usually fine to medium in texture and alternate with much coarser garnet-poor or garnet-free bands. Soda feldspar is predominant in garnet bands while potash feldspar (mainly perthite) characterizes the others. The bands or "layers" in general do not accord with the structure of the country rocks in the discordant type. The term "layered pegmatites" best express the internal structure of such pegmatites.

The pegmatitites of the Anderson Ridge area are believed to be of magmatic origin. Evidences of forceful intrusion of these bodies are mainly lacking. The pegmatitic fluids were intruded along fracture, foliation and/or bedding planes accompanied by assimilation of the older rocks. Concordant pegmatite magmas followed the main planes of the country rock, widening these, and in part replacing the original host rock. Discordant pegmatite control is not known, but the mechanism of intrusion was similar. Apparently excess pegmatitic fluids permitted assimilation and replacement of the country rock to a large extent.

Age relationships of the different pegmatite types have not been fully ascertained. Absolute age dating would help in this regard.

Beryl is the most important economic mineral in the area. The very coarse pegmatites represent the favorable host. These pegmatites are also a possible source of commercial feldspar and scrap mica. Graphic granite pegmatites might furnish commercial feldspar under favorable market conditions. No vugs, pockets or cavities are known for the Anderson Ridge pegmatites and gem or collector item varieties of pegmatite minerals are absent.

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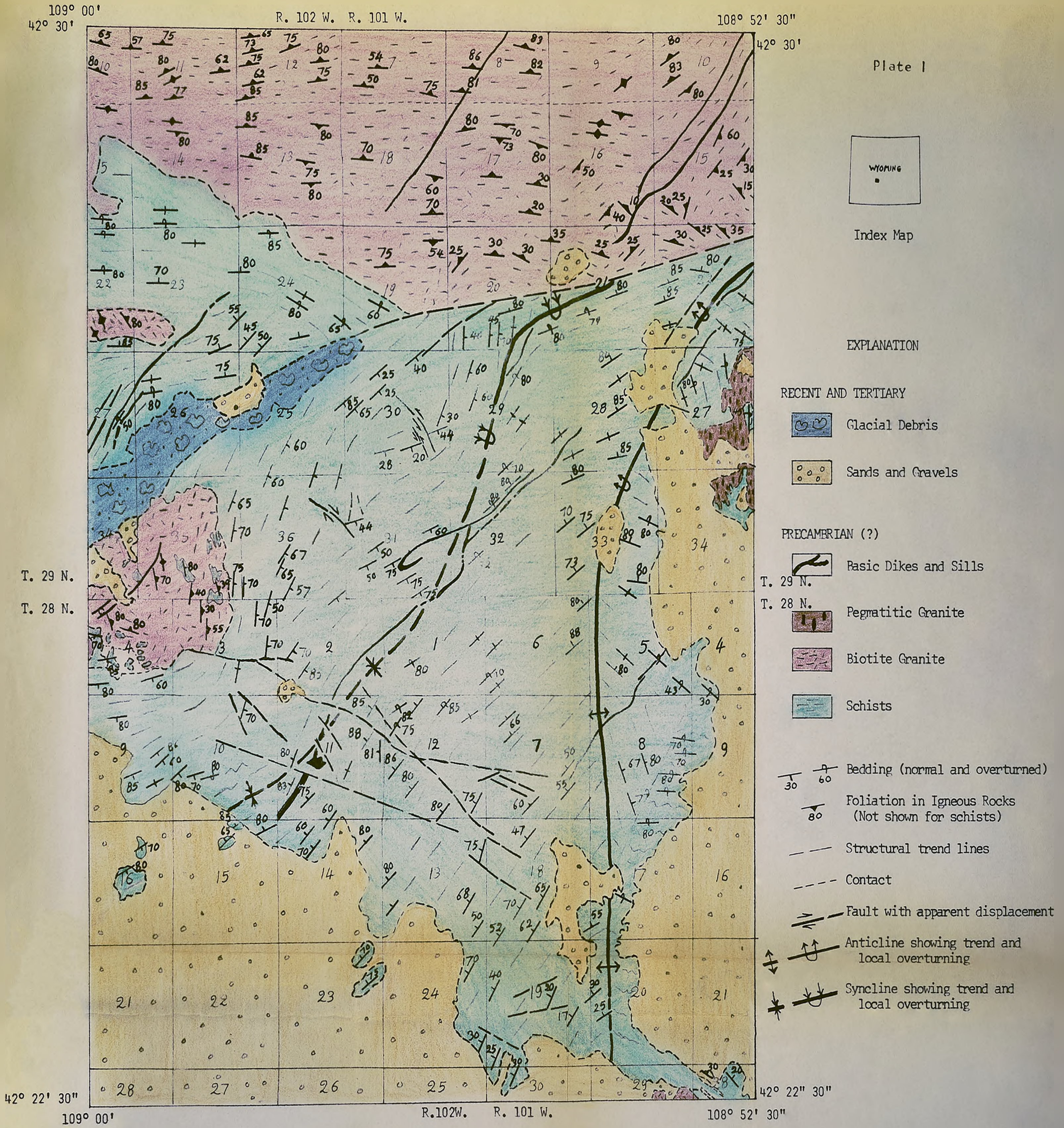
VITA

The writer was born in Cairo, Egypt in 1938. In 1946 he joined Dr. A. Maher Model Primary School and graduated in 1950. He joined the Khedivieh High School in Cairo and graduated in 1955. In the same year he entered the Faculty of Science, Cairo University majoring in geology. In 1959 he received his B.S. (Special in Geology) with distinction and honor degree. Since graduation he worked as instructor of Economic Geology in the Geology Department of the Cairo University till he came to the U.S.A. in a government mission for studying mining geology.

The author is a member of the Geological Society of Egypt and the Science-Professions Syndicate. He is also a member of the earth-sciences honary society of Sigma Gamma Epsilon and the honary scientific research society of Sigma Xi.

Plate I



Geology after:
P. D. Proctor
C. H. Johnson
H. A. El-Etr

TECTONIC MAP OF

ANDERSON RIDGE QUADRANGLE

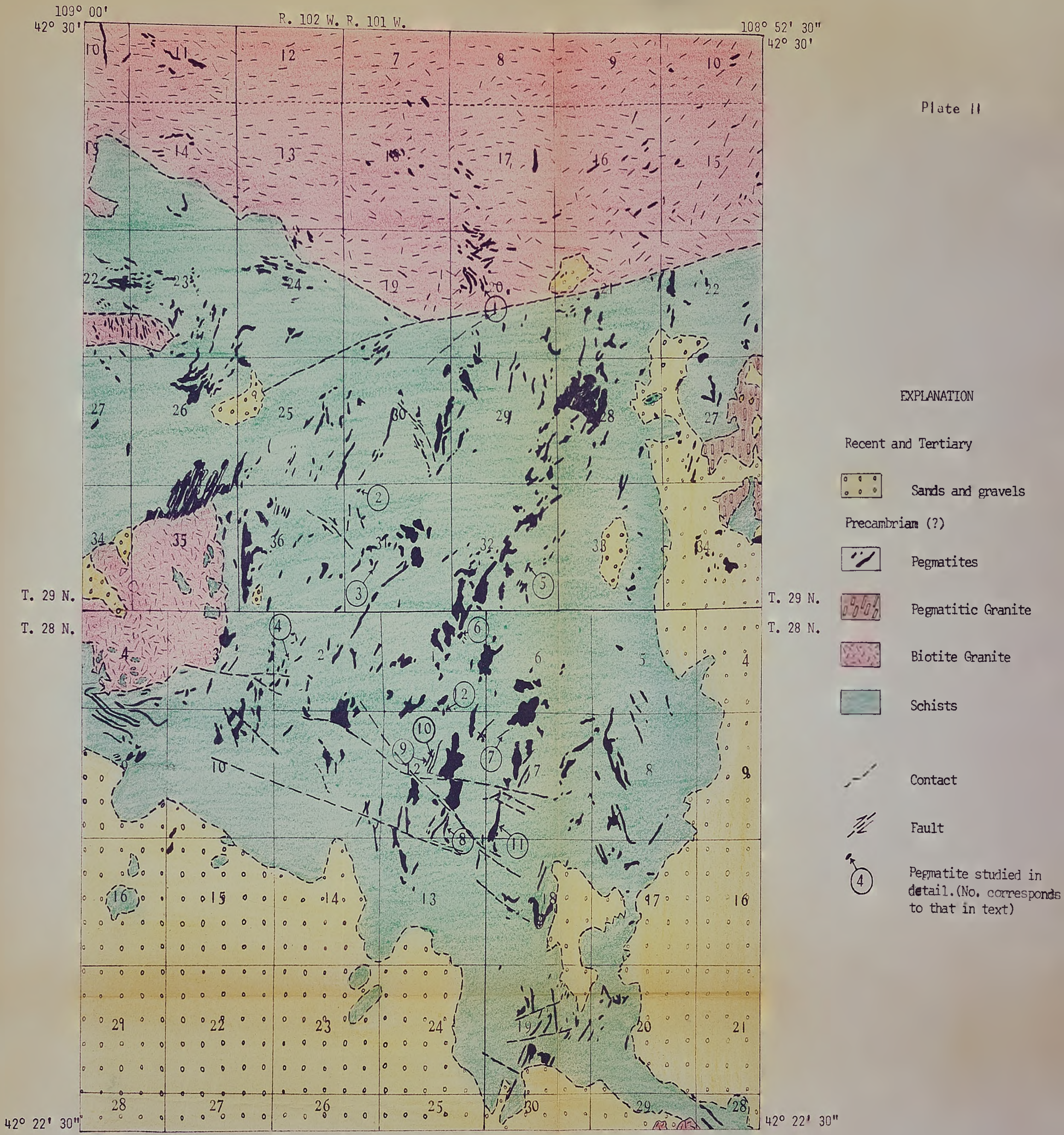
Fremont County, Wyoming

0 1 2 miles

Scale

1961-3

Plate II



PEGMATITE DISTRIBUTION MAP

ANDERSON RIDGE QUADRANGLE, FREMONT COUNTY, WYOMING

1000 0 1000 2000 Ft.

Scale

16°

N M.N.

After P. D. Proctor & H. A. El-Etr, 1962