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MINERALOGICAL AND GEOLOGICAL INVESTIGATION OF THE TERRY URANIUM PROSPECT NEAR MONTICELLO, NEW MEXICO

By

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INTRODUCTION

During the summer of 1954 a study of the Terry Uranium Prospect near Monticello, New Mexico was undertaken. The purpose of the investigation was to make a study of the geology of the area, which to the knowledge of the author had never been done previously, and of the mineralogical assocations using the apparatus available at Columbia University.

The project was carried out under the supervision of Professer Paul F. Kerr of Columbia University. The work was sponsered by both Columbia and the New Mexico Bureau of Mines. The latter also provided field equipment during the summer. The author is much indebted to Dr. Eugene Calligan, director of the New Mexico Bureau of Mines, for his advice in carrying out the field investigation. He wishes, alsp, to thank Mr. Anthony J. Wise for his valuable assistance in the field.

The Terry Uranium Prospect is located about one and one-half miles north of Monticello, a small village at the southern end of the San Mateo Mountains in New Mexico. It is accessible by good dirt roads to within a few hundred feet.

The relief in the immediate area of the prospect is about 200 feet, the approximate elevation about 4000 feet. The country is arid, juniper and sage being the common forms of vegetation.

GEOLOGY

LITHOLOGY:

The Terry Prospect is located in an area of sedimentary and intrusive rocks surrounded on all sides by either volcanics or quaternary gravels. For this reason it has been difficult to relate the geology to adjacent areas. Four major rock types are found in the immediate vicinity of the prospect: (1) Limestone, (2) Silicified limestone, (3) Sandstone, and (4) Quartz monzonite. Although the quartz monsonite and sandstone have also been silicified in areas, the difference is not so striking; hence, they have not been classified as silicified and unsilicified.

An abundance of crinoid stems in the limestone and the presence of silicified woody material in the sandstone strongly suggest that the beds agree with strata known to be of Carboniferous age. The interbedding of sandstone and limestone with some bands of shaly material in the limestone also fit the description of the Carboniferous Magdelena group as described by Rothrock, Johnson, and Hahn (1946).

The common association of fluorspar with late Cretaceous and early Tertiary monzonitic intrusions throughout the state of New Mexico suggests that the quartz monzonite sill at The Terry Prospect is most probably of the same age.

STRUCTURE:

On a regional scale the sediments strike roughly north-south and dip east at 30 to 50 degrees. In the immediate vicinity of the prospect, however, the strike swings abruptly around the nose of an anticline and continues at about S45W. The nose of the anticline may be followed eastward for nearly a mile where it is possible to observe that the beds resume their north-south trend a short distance south of the anticline. Throughout this area the lithology controls the topography to a considerable degree. The sandstone stands up in long north-south ridges, while the silicified limestone is responsible for an occasional prominence. The Terry Prospect is on the west side of one of these long sandstone ridges.

The west slope of this particular ridge consists almost entirely of the outcrop of a quartz monzonite sill. The upper contact of the sill roughly parallels the beds and swings around the nose of the anticline. The lower contact of the sill parallels the beds for nearly half a mile north of The Terry Prospect, but abruptly cuts across the beds near the axial plane of the anticline. The anticline probably preceeded the intrusive developing weakness due to fracturing along the axial plane. This weakness would create a channel way for the upward moving magma thus providing a feeder system for the sill.

At the northern end the sill terminates with an irregular contact along which the sill interfingers with the beds. No indication of injection under pressure was observed in this area; the beds above and below the sill are parallel and continue to be parallel beyond the point where the sill ends. It is quite possible in the light of this evidence that the quartz monzonite made its way into its present location by extensive assimilation.

At the south end of the sill the relationships are obscured by the encroaching gravels. The map gives the erroneous impression that the sill terminates at the prospect workings. This is because the contact between the sill and the block of silicified limestone containing most of the mineralization dips at a shallow angle to the west. At a depth of only a few feet, therefore, the sill is found to extend out under the gravel fill. In spite of an exhaustive search, no indications of bedding and therefore no indications of orientation were found in the isolated block of silicified limestone.

This mineralized limestone may be a disoriented block suspended in the quartz monzonite or it may actually be a part of the wall. In the latter case it would be oriented, but would make a discordant contact with the underlying quattz monzonite. Within the block and the ajacent quartz monzonite there is much brecciation which served as an excellent host for the mineralization. The origin of this breccia is most likely attributable to the late stage solutions from the intrusive. These may have dissolved material along fractures in both the limestone and the quartz monzonite to cause what might be termed a collapse breccia.

Running through the breccia there is a gouge zone which, as shown in Fig. 2 is nearly vertical. No displacement was observed but it may possibly be a large enough feature to partially account for the high degree of mineralization in the vicinity. Also running through the brecciated area are narrow vertical zones of Caliche. These are believed to be secondary features occurring at a time long after the mineralization. Weathering may have widened fractures and carried calcite from nearby limestone to fill them.

DETAILED DESCRIPTION AND IDENTIFICATION OF THE QUARTZ MONZONITE

The intrusive is moderate to light colored. In the hand specimen it is clearly porphyritic with phenocrysts of less than one millimeter in size. These phenocrysts are altered to kaolinite and readily weather out on surface exposures giving the appearance of a rock full of small cavities. The rock as a whole is softer than the surrounding silicified sediments and therefore causes a depression in the west slope of the ridge.

The high degree of alteration makes only an estimate of the original composition feasible in thin section study.

Estimated Original Composition of the Intrusive

Plagioclase (oligoclase?)...................... 65%
Quartz.. 25% = qtz. diorite
Apatite... 1%
Magnetite.. 2%
Potash feldspars................................. 2%
(suggested by the shapes of some of the phenocrysts)
Pyroxene or Hornblende....................... 5%
(suggested by the presence of chlorite as an alteration product)

In its present state the rock consists largely of alteration products:

Kaolinite (from feldspars)
Sericite (also from feldspars
Chlorite (possibly from pyroxenes)

The typical polysynthetic twinning of the plagioclases may still be seen in places where alteration to kaolinite or sericite is incomplete. The original quartz remains unaltered, but the addition of later hydrothermal quartz makes estimation of the original quantity difficult. On the bases of the information given above the author has concluded that the sill material was originally a quartz monzonite or an igneous rock of similar composition.

RADIOMETRIC SURVEY:

A radiometric survey of the area was run with a nucleometer. The intensity of the radiation and the configuration of the radioactivity is indicated on the map by contour lines. The contours show three centers of high radioactivity, each with a down hill projection due to transport of radioactive boulders and gravel in normal surface erosion.

THE WORKINGS:

The workings consist of a pit 15 feet deep, 17 feet long, and 10 feet wide. It is this pit that afforded the exposure shown in Fig. 2. On either side of the pit there are two very shallow bulldozer trenches.

All of the workings broke through the silicified limestone into the underlying quartz monzonite.

MINERALOGICAL INVESTIGATION

LABORATORY EQUIPMENT USED:

Thin sections and fragments examined under a polarizing microscope provided much information. A binocular microscope was also used.

X-Ray Diffraction:

An x-ray powder camera was used in the investigation of uranium minerals and the kaolinite. The sample was powdered and placed in the center of the cylindrical Debye Camera where an x-ray beam of characteristic copper radiation impinged on it. The x-rays were reflected at various angles by planes of atoms in the mineral sample and recorded on photographic film on the inside surface of the cylinder. According to Bragg's law the angle of reflection is a function of the interplanar spacing when the wave length is kept constant. It was possible, therefore, to determine the interplanar spacings of the atoms in the mineral, and by comparing them with the compiled data in the ASTM Index (1953) preliminary identifications were made.

Differential Thermal Analysis:

This instrument consists of a pair of thermal couples placed electrically in series so that the potential of one opposes the potential of the other. A thermally inert substance (Al_2O_3) surrounds one couple and the sample is packed around the other couple. The whole assemblage is then heated in an electric furnace at a constant rate of 12°C/min until a temperature of 1100°C is attained. As long as both couples are at the same temperature, no current flows. As soon as one is either hotter or colder than the other, however, a current flows and is registered on a graph (L. & N. Recorder) which at the same time records the temperature of the furnace. The graph then shows accurately the temperatures of reactions which either yield or absorb heat. These reactions show up on the graph as deviations from a base line, the direction of deviation indicating whether the reaction is exothermic or endothermic. Reactions commonly causing such effects are loss of water of crystalization, decomposition, and change or breakdown in crystal structure. This method of mineral identification is discussed in greater detail by Kerr and Kulp (1948).

Autoradiographs:

This method consists simply of placing the flat surface of a sawed rock against a photographic film which is sensitive to alpha particles. When the film is developed, dark spots consisting of thousands of microscopic streaks indicate the location of the radioactive minerals. The film may be laid on the rock surface for careful location.

DISCUSSION OF INDIVIDUAL MINERALS:

Silica Minerals:

On a quantitative basis the silicification is the principal phase of the mineralization. It represents the removal of large quantities of carbonates and the introduction of vast amounts of silica. In the immediate area of the prospect the silicification forms a rough aureole around the intrusive. Along the contacts the sediments and even the quartz monzonite are silicified. Away from the intrusive, however, the silicification diminishes. Although a fairly sharp contact may be drawn between the limestone and the silicified limestone, there is a fringe zone in which the limestone is 90% or more calcite but contains silicified crinoid stems and chalcedony in fracture planes.

The silica shows preferential replacement of calcite in place of cavity filling in the breccia zone. Here the fragments are chalcedony while the cavities are filled with fluorite, kaolin, uranium minerals or remain empty. In thin section, however, some of the cavities show a lining of quartz crystals. In the sandstone and quartz monzonite the introduced silica behaved as a cementing agent or filled fractures.

Iron and Manganese Oxides:

Much of the silicified limestone is colored red, brown, maroon, and black. These colors are attributed to staining by iron and manganese oxides. In the sediments stains are associated with the silicification. There is an abundance of iron staining in the quartz monzonite as well, undoubtedly due to the oxidation of the magnetite. The black manganese occurs as a coating on fracture planes and surfaces of the silicified limestone unlike the iron oxide, which is to be found in the chalcedony.

Fluorite:

Fluoritization is difficult to recognize in this area, for the fluorite weathers so much faster than its silicified matrix that it usually leaves nothing behind but skeletal cavities. Since the fluorite occurs as breccia filling, its removal by weathering leaves the rock with countless breccia fragments projecting from its surface. This feature has a peculiar appearance and is easily recognized in the field providing a fairly reliable criterion for fluoritization. When this criterion was applied to the silicified limestone surrounding the sill the fluoritization was found to be remarkably extensive. Where the workings have exposed fresh rock, the fluorite may be readily observed. Here it was found in the brecciated quartz monzonite as well as the silicified limestone. Megascopically the fluorite is always found as breccia filling.

The color of the fluorite seemsto be a direct function of the radioactivity. At the center of the pit where the count is highest the fluorite is so dark as to be opaque in hand specimen. In thin section this material was found to be a very deep purple although the color is sporadic.

In the thin section study of the brecciated material from the pit two types of fluorite were observed. One is a fine grained material which originally filled the breccia spaces. The other is a more coarsely crystaline variety formed in the little veinlets which cut the breccia fragments and the breccia fill as well. These veinlets also contain more coarsely crystalline quartz. They most likely represent a later phase of the silica and fluorite mineralization.

The coarsely crystalline fluorite shows color banding under the microscope. The bands usually occur along planes of crystal growth and are probably due to slight variations in trace element composition or crystalographic imperfections affecting the susceptibility of the fluorite to coloration by irradiation from the nearby uranium minerals.

When the dark fluorite was heated to several hundred degrees centigrade it became white. X-ray powder photographs were made of the different colored fluorites and of the fluorite that had been heated. No significant variations were found by this procedure but ample identification of fluorite was provided. Some of the darkest fluorite was ground and analyzed for uranium both by x-ray fluorescence and by borax bead test. Both of these tests were negative indicating that the fluorite contains only very minor amounts of uranium if any.

In a hand specimen casts of fluorite crystals were found in silica indicating that at that point the fluorite preceeded the silica. In one of the thin sections, however, fluorite was found filling a cavity by growing on top of quartz crystals indicating that the fluorite followed the silica. The only conclusion that can be drawn from these seemingly contradictory pieces of evidence is that the silica and fluorite were virtually contemporaneous, first one predominating then the other.

<u>Uranium minerals:</u>

Four uranium minerals were identified:

1. Uranophane
2. Tyuyamunite
3. Carnotite
4. Uraniferous opal

Uranophane occurs as inclusions in the silicified limestone fragments of the brecciated zone and as well developed primatic crystals in cavities throughout the brecciated zone. It is commonly associated with kaolinite in these cavities.

Some of the well formed yellow needles were ground and placed in the x-ray powder camera. Inter planar spacings are given in the following table:

YELLOW NEEDLES		URANOPHANE *	
I	d(Å)	I	d(Å)
10	7.89	10	7.89
2	6.55	3	6.58
2	5.43	2	5.411
4	4.792	3	4.808
1	4.267	2	4.267
5	3.948	5	3.948
2	3.504	2	3.504
3	3.196	3	3.201
3	2.985	3	2.987
3	2.901	2	2.902
1	2.704	2	2.695
1	2.620	2	2.621
1	2.526	1	2.548
1	2.189	1	2.199
1	2.097	2	2.098

In the northern trench the north facing wall shows a great deal of yellow coating. This material is flaky and almost entirely surficial. It is quite possible that it formed after exposure by the bulldozer. This material was identified as a mixture of tyuyamunite and carnotite by the x-ray data given in the table below:

YELLOW COATING		TYUYAMUNITE **		CARNOTITE	
I	d(Å)	I	d(Å)	I	d(Å)
10	10.27	10	10.18		
1	6.36			10	6.42
3	5.007	9	5.019		
1	4.037				
1	3.373	3	3.366		
3	3.218	5	3.202		
1	2.624				
1	2.154	1	2.159		
1	2.034	4	2.039		

Pictures of the yellow coating from other specimens showed no tyuyamunite lines but showed only a very faint line at about 6.4 to 5.5. Carnotite is probably present in fairly large amounts but for some reason does not give a good x-ray photograph. Perhaps it is too finely crystalline.

The uraniferous opal is the only mineral present in the specimens from The Terry Prospect which was found to be fluorescent under ultraviolet light. Under the binocular microscope the material could be seen to have the typical botryoidal form often characteristic of opal. The material was readily identified under the polarizing microscope with the aid of refractive index liquids. It was found to have an index between 1.460 and 1.465. This falls within the range generally accepted for opal (1.40-1.46)(Rogers and Kerr - 1942). It was also isotropic under crossed nicols. These properties are felt to be satisfactory for the identification of opal.

* Hamilton and Kerr (1953)
** Vaes and Kerr (1949)

The further identification of the material as uraniferous opal was accomplished with the aid of autoradiographic film. A fragment of the opal was taped to the film for several days. When the film was developed, alpha tracks were found where the fragment had been, indicating the presence of radioactivity in the opal. The green fluorescence of the opal is a good indicator that the radioactivity is due to uranium.

Clay Material:

Clay occurs in two ways at The Terry Prospect, as altered phenocrysts of feldspar in the quartz monzonite and in cavities in the brecciated zone. The latter are found in sizes an inch across and smaller. It was not possible to obtain enough of the clay from the phenocrysts to run a differential thermal analysis. The clay in the breccia was run and a curve obtained as given in Fig. 3. This curve shows an endothermic peak at about 630°C and an exothermic peak at about 9[illegible]0°C. This compares favorably with a curve for kaolinite from Gordon, Georgia given by Speil et al., (1945). In Speil's curve there is an endothermic reaction at 630°C and an exothermic reaction at 980°C.

X-ray photographs were run on both occurrences of clay from The Terry Prospect. The high degree of similarity between the two pictures is good evidence that they are both the same mineral. The picture of the breccia clay was clearer and was, therefore, measured for identification purposes. The d(Å) values for this clay are listed in the following table along with the values for kaolinite as given by Brindley and Robinson (1944-6).

X-RAY DATA FOR THE CLAY

CLAY		KAOLINITE	
I	d(Å)	I	d(Å)
10	7.13	10	7.15
4	4.436	5	4.45
4	4.168	6	4.17
10	3.588	10	3.57
1	2.561	7	2.55
1	2.499	8	2.436
1	2.389	7	2.3[illegible]4
2	2.341	9	2.331
1	2.301	8	2.284
1	2.199	3	2.182
1	1.999	7	1.985
1	1.939	4	1.935
1	1.893	2	1.892
1	1.846	4	1.835
1	1.789	6	1.778
1	1.667	8	1.659
1	1.623	7	1.616
1	1.592	4	1.581
1	1.544	6	1.539
2	1.492	9	1.486

The kaolinized phenocrysts in the quartz monzonite probably formed as the result of alteration of the feldspar by hydrothermal solutions. The kaolinite formed in this way may have been transported for some distance into the brecciated limestone by the hydrothermal solutions. This would account for the kaolinite filled cavities in the mineralized zone of the silicified limestone. According to Grimm (1953), hydrothermal origin is not uncommon for kaolinite.

CONCLUSION

From the observations made in this study, it is possible to come to conclusions concerning the sequence of events as follows:

Interbedded limestones and sandstones were deposited in late Paleozoic. They were subsequently tilted to an easterly regional dip between 30 and 50 degrees. Possibly during the tilting some folding took place bringing about an arching of the beds into an anticline. Along the axial plane of the anticline fracturing took place. Rising along the fracture zones a magma of quartz monzonite composition moved upward forming a dike. When it reached a zone of limestone and shaly limestone between two beds of sandstone, it spread out to form a sill. Apparently much of the limestone and shaly material was assimilated as there is little indication of forceful injection.

During the late stages of crystallization of the magma an abundance of silica was transported from the sill to the rock surrounding the sill. Since there is good evidence that the fluorite both preceeded the silica and followed it, these two materials are considered to be simultaneous. It has not been possible to confirm the relationship of the uranium minerals from the evidence offered by this deposit. In other localities, however, such as Marysvale, Utah and Grants, New Mexico, uraninite is found intimately associated with fluorite indicating simultaneity of formation. Although no uraninite was found at the Terry Prospect, it probably was the primary mineral formed at the time of hydrothermal activity.

As erosion took place bringing the deposit closer to the surface, ground water penetrated fractures and small cavities converting the primary uranium minerals into the secondary ones as found today.

EXTENT OF THE MINERALIZED ZONE:

The location of the prospect on the border between the rock outcrop and the deep valley fill limits knowledge of the extent of the mineralized zone under the fill. If as suggested, the mineralized block of silicified limestone is merely a disoriented block suspended in the quartz monzonite, then one might expect the mineralization to be limited to the relatively small block. There is, however, a reasonable possibility that there are other blocks and other quartz monzonite-limestone contacts favorable to mineralization under the fill. The presence of such blocks could be ascertained only by exploration.

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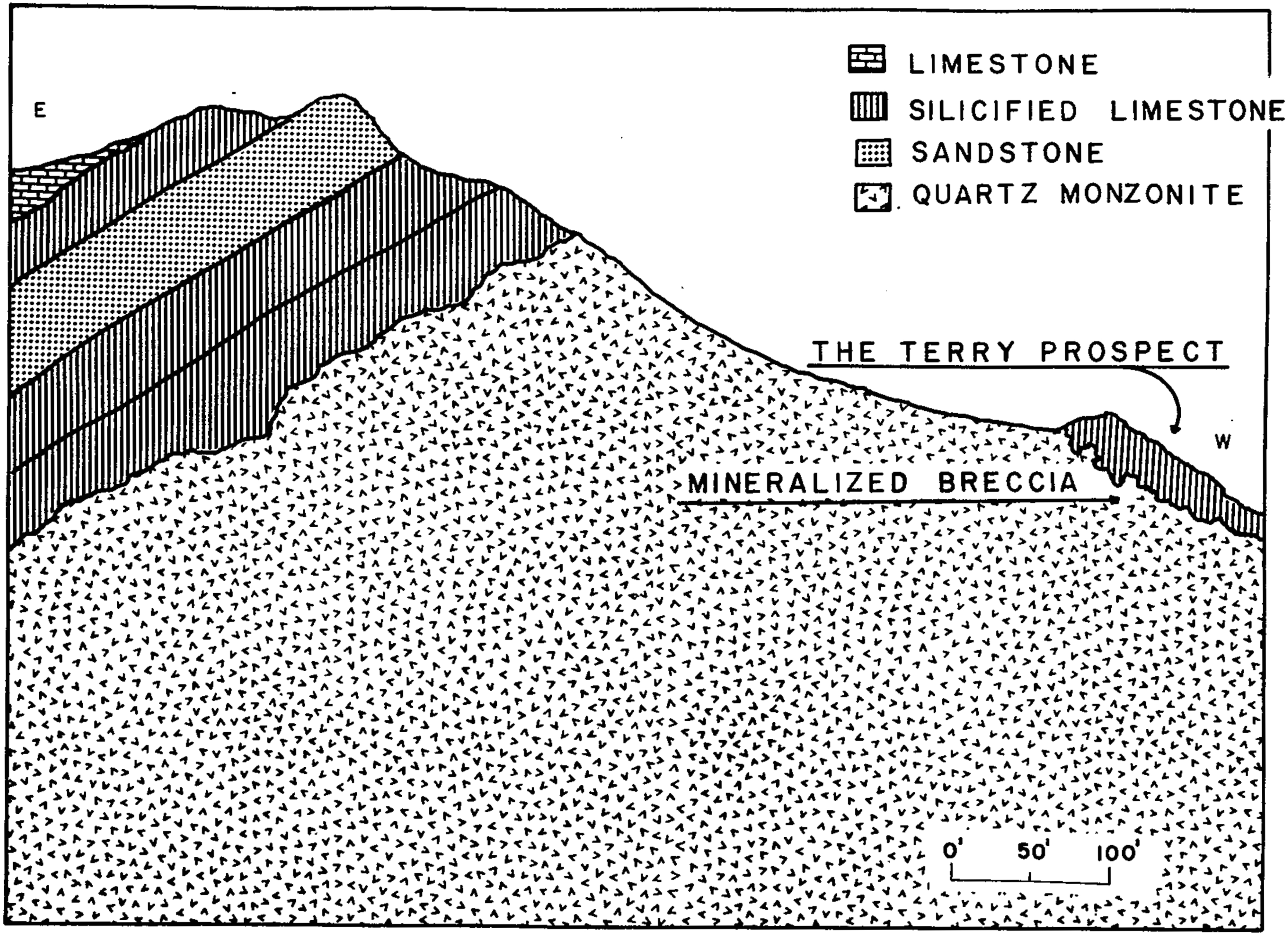

FIG. I GENERALIZED CROSS SECTION THROUGH THE TERRY PROSPECT

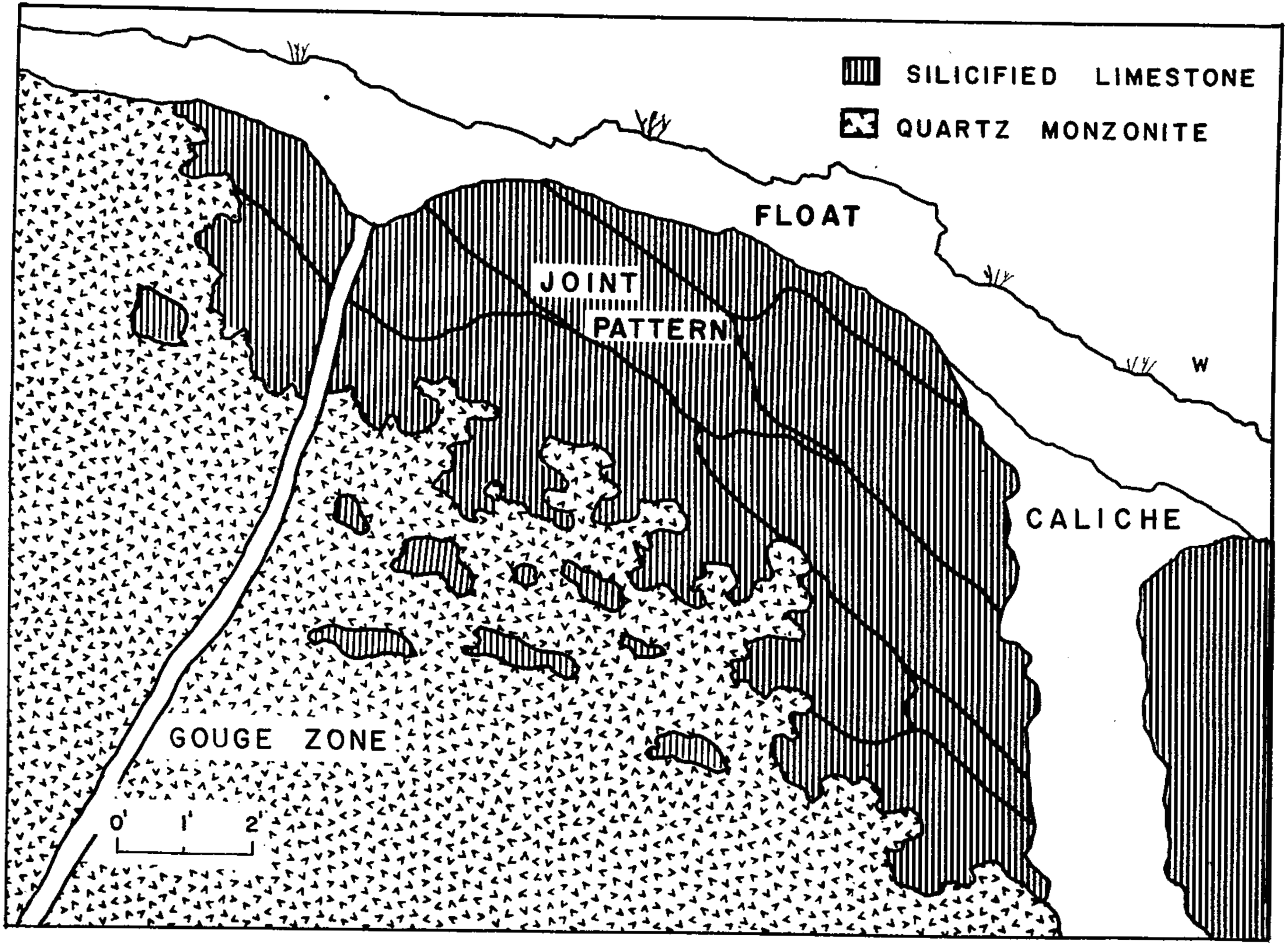

FIG. 2 SOUTH WALL OF THE PIT
BRECCIATED ZONE

DTA

CLAY FROM BRECCIA ZONE

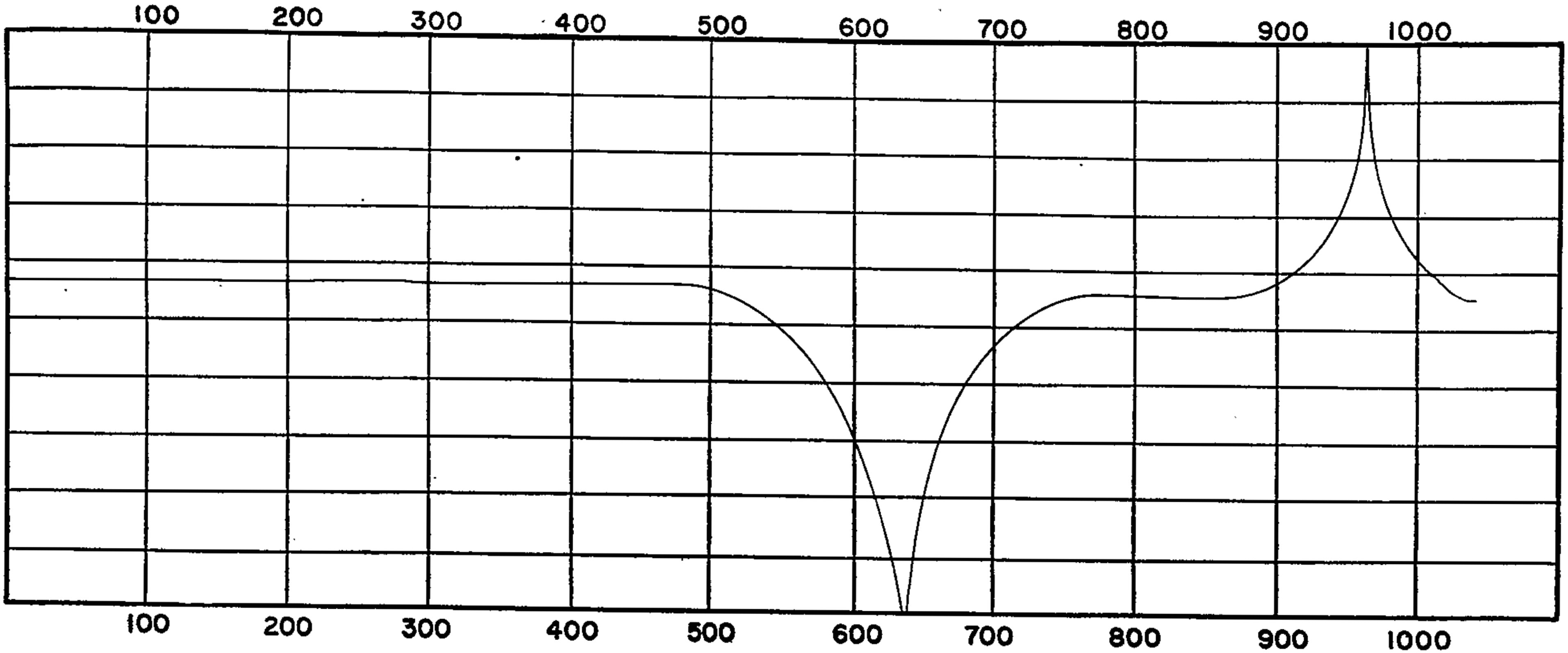

FIG. 3