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1982, pp. 203-210. https://doi.org/10.56577/FFC-33.203

in:

Albuquerque Country II, Wells, S. G.; Grambling, J. A.; Callender, J. F.; [eds.], New Mexico Geological Society 33 rd Annual Fall Field Conference Guidebook, 370 p. https://doi.org/10.56577/FFC-33

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PRECAMBRIAN ROCKS OF A PORTION OF THE PEDERNAL HIGHLANDS, TORRANCE COUNTY, NEW MEXICO

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INTRODUCTION

The Pedernal Highlands are located in Torrance County, New Mexico, approximately 60 km east-southeast of Albuquerque (fig. 1). They represent a remnant of the ancestral "Rocky Mountains" and are seen today as gently rolling hills of eroded Precambrian rocks. The Pedernal Highlands form a narrow north-trending plateau about 70 km long and a few kilometers wide. The most prominent topographic feature is Pedernal Mountain with an elevation of 2,307 m, about 245 m higher than the surrounding plains.

The Precambrian core of the Pedernal Highlands is composed of metavolcanic, metasedimentary, and meta-intrusive rocks. In this study they are divided into four broad lithologic units which, from north to south, are: northern quartzite terrain, T-phase lithology, M-2 volcanics, and Crab Hill volcanics (fig. 1).

Metamorphic grade ranges from lower to middle greenschist facies. The predominant foliations are axial plane cleavages and transposition foliations which generally strike east and dip steeply to the south.

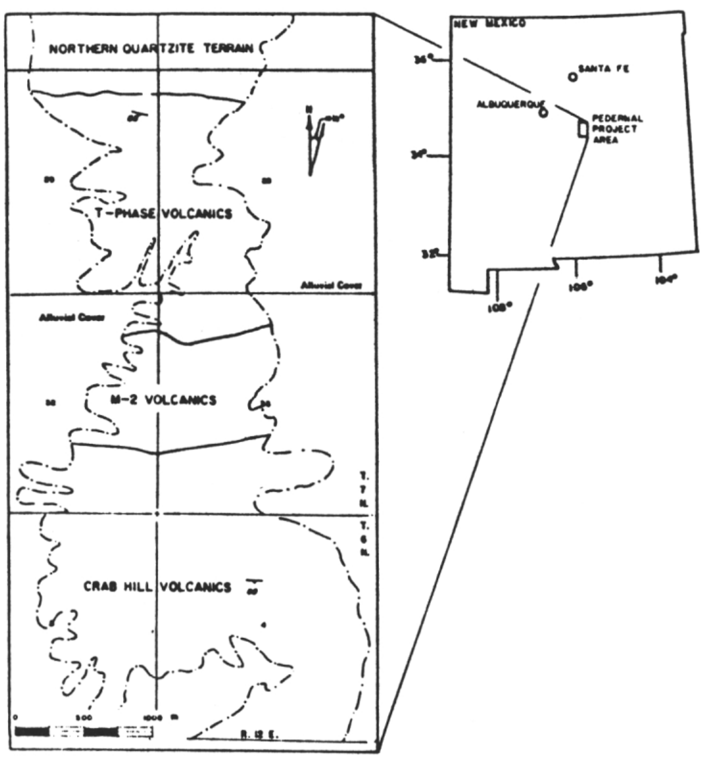

Figure 1. Location map and general geologic divisions in the Pedernal area.

Polyphase deformation has produced extremely complex outcrop patterns and rendered precise stratigraphic correlations nearly impossible. Post-metamorphic faulting is sparse except along the extreme western edge of the highlands. An Rb/Sr date of 1493±30 30 m.y. was obtained on a sample of M-2 metavolcanic rhyodacite (dated by R. L. Armstrong, University of British Columbia), and a metagranite in the southern part of the study area was dated at 1416± 100 m.y. It is possible that both dates have been partially reset by metamorphic recrystallization. Narrow dikes of post-metamorphic syenite are 469 7 m.y. old (Loring and Armstrong, 1980).

The Precambrian rocks of the Pedernal Highlands have been studied previously by Fallis (1958), Woodward and Fitzsimmons (1967), Gonzales (1968), and Gonzales and Woodward (1972). These authors divided the Precambrian into granites, schists, cataclastic rocks, heterogeneous units, and quartzite.

DEFORMATION EFFECTS

Deformation in the Pedernal rocks varies markedly and has a profound influence on stratigraphic interpretation. These effects are summarized briefly in the following section to provide a foundation for the stratigraphic discussion below. A gradual increase in the number of foliations and an increase in the overall complexity of the structure is seen from north to south.

In the T-phase metasediments, original bedding is distinct and individual outcrops show few minor folds, although stratigraphic facing reversals indicate major isoclinal folds with axial planes (and an axial plane slaty cleavage) which trend northeasterly. The primary features of all lithologies south of the T-phase metasediments have been substantially modified by repeated small scale folding.

The boundary between the T-phase metasediments and the M-2 suite marks an abrupt change in the dominant layering trend (from northeasterly to easterly) and in the outcrop pattern of units. The layering trend in the M-2 suite is parallel to second generation foliation, S„ and layering is lenticular at both outcrop scale (fig. 2) and map scale (fig. 3). Small isoclinal F_2 folds are relatively common in certain lithologies (figs. 4, 5), but overall these structures are rare. We interpret the lenticular nature of layering at all scales to be the result of transposition during an F_2 fold event.

In the Crab Hill suite, the map-scale pattern is the same as in the M-2 suite, but at the outcrop the F_2 foliation is commonly transposed by a third generation foliation. Local development of later generations of structures further complicates the situation in the Crab Hill suite.

Map-scale transposition produces an overall mixture of lithologies (fig. 3) within which original stratigraphic relations are uncertain; and major boundaries, such as the contact between the T-phase, M-2, and Crab Hill suites, are difficult to define. In particular, possible sedi-

Figure 2. Typical fine transposition layering in the M-2 volcanic suite. Layers are lenticular and parallel to the S_2 foliation. Bar is 2.5 cm long.

mentary facies changes cannot be recognized. The pervasive tight folding and disruption of the primary layering complicates identification and interpretation of original lithologies. One specific problem in this area is that repeated transposition, particularly in the Crab Hill suite, produces a "fragmental" rock (fig. 6) that is superficially similar to many volcanogenic breccias in the area.

PSEUDOSTRATIGRAPHY

The following is a discussion of the protolith groupings in the study area. For the reasons described in the section above, no time-ordered stratigraphic sequence can be given nor is any inferred.

Each igneous group is based on characteristic mineralogic assemblages. Designation of sedimentary protoliths are based on rock chemistry.

Northern Quartzite Terrain

Pedemal Mountain is part of a thick Precambrian quartzite sequence which has been described as iron formation by Woodward and Fitzsimmons (1967). The northern quartzite terrain consists of thin beds of hematite-rich percent Fe) quartzite within a thick sequence of very pure quartzites. The parent lithology was a pelagic chert, with interbedded ferruginous layers probably created during deposition by fluctuations in oxygen fugacities in the sea water.

South of the quartzites is a rock suite which represents a transition from a period of mixed volcanic and sedimentary deposition (T-phase suite) to deposition of pelagic chert (northern quartzite terrain). These transition rocks are comprised of metacherts and metapelites which are complexly interlayered and structurally deformed.

T.Phase Lithologies

The major member of the T-phase suite is a mafic laharic breccia complex with interbedded rhyolitic to rhyodacitic flows and pyroclastics. The laharic breccias are composed of rounded to very angular fragments ranging in composition from mafic (diabase) to silicic (rhyolite and chert) set in a fine-grained greywacke matrix of probable andesitic derivation. Fragment size ranges from less than a millimeter to as much as 25 cm in diameter. Sorting of the fragments, according to size or type, is totally absent. These volcaniclastic breccia units are "epiclastic breccias." Other volcanic rocks in the T-phase are fine-to-medium-grained andesitic to basaltic pyroclastics and minor flows.

Sediments are fine-to-medium-grained greywackes and are apparently derived largely from local tuffaceous units. Graded bedding and cross-laminations are very common in these units.

M.2 Volcanics

An important part of the M-2 volcanics is represented by a fine-to-medium-grained pyroclastic andesite that is well laminated and shows no apparent post-depositional hydrothermal alteration. Numerous lenses of epiclastics occur interlayered within this andesite and are commonly laterally discontinuous. The epiclastics are fine-to-medium-grained and composed of reworked andesitic material; locally they show cross-laminations and graded bedding.

The mafic component within the M-2 volcanics, a laharic breccia unit, consists of rock fragments of various sizes and lithologies supported in a matrix of fine-grained mafic(?) pyroclastic material. The rock fragments usually show varying degrees of milling, common during deposition of debris flows (Fisher, 1960). Another feature common to both debris flows and this unit is the total lack of sorting.

The silicic members of the M-2 package are primarily rhyodacites and rhyolites which are, for the most part, pyroclastic. Grain size in the units is uniform, ranging from 1 to 5 mm in diameter. These units are comprised of 10-30 percent plagioclase phenocrysts set in a matrix of quartz, orthoclase, epidote, sericite, biotite, and chlorite. Accessory minerals consist of trace magnetite, hematite, and zircon. Plagioclase phenocrysts are usually replaced by sericite up to 40 percent by volume. Matrix orthoclase, though partially replaced by sericite, is relatively free of any chlorite.

The rhyodacite flows are apparently flow-banded and contain up to 5 percent plagioclase phenocrysts, which are set in an aphanitic matrix of quartz and orthoclase plus accessory zircon, epidote pyroxene(?). The plagioclase phenocrysts show partial replacement by potassium feldspar and embayed borders with quartz plus potassium feldspar overgrowths. Matrix material appears to be recrystallized devitrified glass.

Figure 7 is a photo of brecciated pyroclastic and flow rhyodacite members. Where the units are brecciated, the matrix lithology is apparently andesitic or altered rhyodacitic debris. The breccia fragments do not appear to be altered beyond development of a thin reaction rim. This breccia appears to be a primary volcanic feature.

The M-2 sequence "iron formation" consists of a thin (-1-m thick) laminated quartzite ± magnetite assemblage. One subunit contains as much as 20 percent magnetite by volume and minor supergene copper mineralization. Laminations within this unit range from a few microns up to a maximum of 5 cm. This unit is believed to be of volcanogenic exhalatiVe origin.

Sediments of the M-2 cycle appear to have been derived from freshly deposited nonindurated volcanics. They are sub-greywackes with a seemingly local provenance and are fine-grained, light green to olive drab, well-laminated epiclastics. These sediments are composed of varying

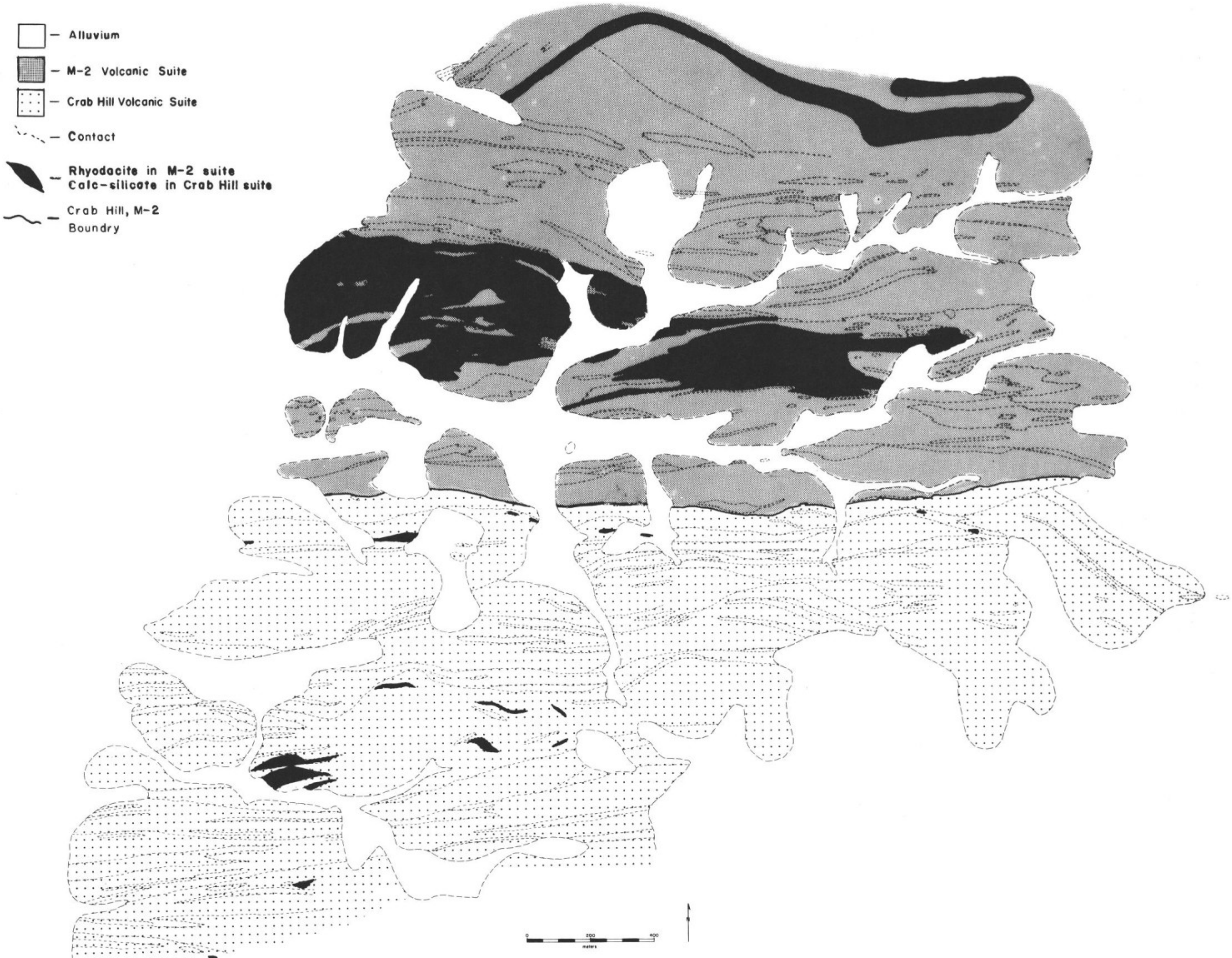

Figure 3. Portion of a detailed geologic map of the central Pedernal area, showing the mixture of lithologies and the lenticular nature of the M-2 and Crab Hill suites at map scale.

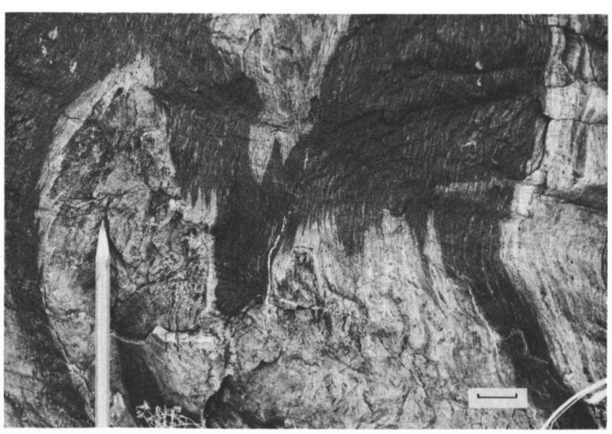

Figure 4. Mesoscopic F_2 fold in the M-2 suite. The axial-plane foliation in the dark layer is a mineralogically differentiated crenulation cleavage. Warping of the axial plane and small kinks visible in the axial plane foliation are F_4' structures. This style of fold is rare in these rocks. Bar is 2.5 cm long.

Figure 5. Small F_2 fold in rhyodacite in the M-2 suite. This is the most common style of fold in this lithology. Bar is 2.5 cm long.

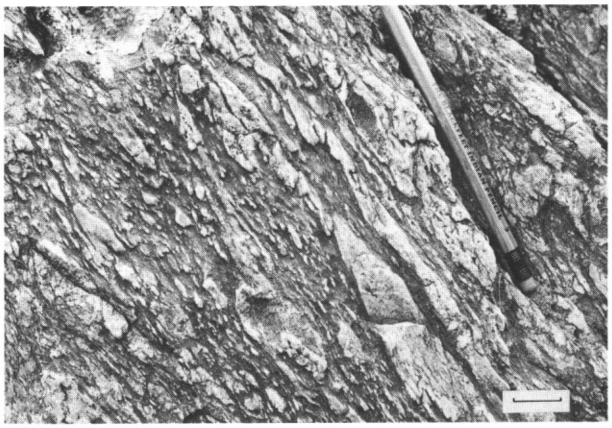

Figure 6. Tectonic breccia formed by F_3 transposition in volcanogenic rocks of the Crab Hill suite. It is likely that all the fragments were originally part of continuous layers similar to those at the right of the photograph, which show partial necking and small asymmetric folds with sheared out limbs. The rock in the left part of the photograph is more typical of this unit, but its origin can still be recognized. Many of the fragments are remnants of fold hinges; the fragments are of a single lithology, and groups of similar fragments form en echelon trains to which enveloping surfaces can be drawn. The enveloping surfaces define the earlier layering in the rocks (in this case it is S_2). Bar is 2.5 cm long.

amounts of quartz, clay-altered feldspars, sericite, epidote, hematite, and minor zircon ± apatite.

Crab Hill Volcanics

This suite contains numerous basic to intermediate pyroclastic rocks with thin interbedded quartzite layers (maximum thickness of 15 cm). Based on petrographic studies, the overall composition of this unit is basaltic. However, thin (2 m) interlayered units of andesitic tuffs are common. In thin section, samples from these mafic units consist of actinolite, sphene, and clinozoisite as major constituents with minor biotite, chlorite, magnetite, and albite. These samples usually contain lapilli of various compositions. Of interest in this unit are the numerous thin metachert beds. One can be classified as an iron formation, as it contains approximately 15 percent total iron. These metacherts are laterally discontinuous and never exceed 2 m in thickness.

Various other types of mafic to intermediate rocks are present in the Crab Hill volcanics, and all appear to be pyroclastic. The majority of these are andesitic ash to lapilli tuffs. One of the two uncommon members of this group is a pyroclastic dacite, which may contain a few thin flows. This unit is characterized by abundant plagioclase and quartz phenocrysts. Plagioclase composition is indeterminate due to intense sericite development (up to 70 percent replacement). Quartz phenocrysts are usually much larger than the plagioclase crystals, due to quartz overgrowth. Their average size is approximately 5 mm in diameter.

A strikingly different member of the Crab Hill suite is a calc-silicate complex. This lithology is best described as an intricately inter-laminated sequence of subunits consisting of quartzite, iron formation, and a calc-silicate mineral assemblage. The suite of calc-silicate minerals consists of epidote, diposide, and garnet, with a complement of accessory magnetite, quartz, chlorite, and actinolite. In thin section, fragments of rhyodacitic to dacitic pumice(?) shards are present throughout. These units are postulated to be fumarolic exhalatives. Two of these calc-silicate units contain chalcocite and malachite along foliation (Sd S,-S_2) planes; no hypogene sulfide mineralization has been found. These interlayered subunits are usually less than 5 cm thick with lateral extension of one meter as a maximum. Subunits are no longer discrete layers due to the numerous deformational episodes. They are crudely cylindrical in shape, more accurately described as boudins, which probably developed as a result of F, deformation. They are parallel to L_{20}.

The bulk of the Crab Hill sequence is made up of pyroclastic rhyolites and rhyodacites and their epiclastic by-products, collectively termed quartz "eye" tuffs. The presence of quartz "eyes" is the single most diagnostic feature of these units. Rock textures vary from hornfelsic to porphyritic, with quartz phenocrysts as large as one centimeter comprising 1 percent to 30 percent of the rock by volume. Sericite development is, in places, extreme, replacing and completely destroying parent mineralogy. Relict quartz "eyes" are usually partially preserved, however. Secondary chlorite occurs sparingly and is not as pervasive as sericite.

The sediments of the Crab Hill suite are represented by lenses of epiclastic rocks which are buff grey, competent, and well laminated. Lithologic variation of these epiclastic units is abundant; grain-size distribution is from clay to coarse-grained.

Volcanic units within the sediments are rare. However, a plagioclase porphyry of probable andesite composition crops out near the center of exposed sediments. This unit consists of 15-30 percent zoned plagioclase phenocrysts up to 3 cm long, set in a very fine-grained matrix of chlorite, sericite, epidote, and quartz. All of the plagioclase phenocrysts have alteration rinds of chlorite and sericite. The majority of them are shattered euhedral crystals. The crystals were most likely broken while the unit was emplaced, probably as hypabyssal dikes. The units contain quartz "eyes" and may be, therefore, a true member of the Crab Hill suite.

Figure 7. Primary volcanic breccia from a portion of the M-2 rhyodacite flow assemblage. Fragments are rhyodacite set in a matrix of more mafic rock flour. Bar is 16 cm long.

Post-Volcanic Intrusives

Scattered throughout the entire area are small isolated dikes of various intrusive rocks not directly equated to any defined lithologic package. Their compositions range from diabase to granite. These intrusives are as chemically differentiated as the volcanic rock suite they intrude. The relative age dates of the granites and volcanics cited earlier in this paper suggest the granite is only slightly younger than the volcanics. Sangster (1972) notes that is not uncommon to find a suite of differentiated intrusives within a volcanic pile, and that the intrusives may represent the "magmatic hearth" from which the volcanic pile was derived.

The unusual pink syenite dikes observed in the Pedernal Highlands are post-Precambrian as indicated by both cross-cutting relationships and an age date of 469 ± 7 m.y. (Loring and Armstrong, 1980). These dikes show minor hydrothermal alteration and have in the past been prospected for uranium. The thorium content of these dikes is the apparent source for the anomalously high gamma-radiation counts.

STRUCTURE

The following section generally only refers to that part of the Pedernal area studied in detail (see fig. 1).

Outcrop Structures

The most distinctive structural feature of the Pedernal rocks is the marked increase in complexity from north to south. In the T-phase metasediments and pyroclastics, the main layering is bedding, and the structure is dominated by large, first-generation isoclinal folds with an axial plane trending northeasterly and dipping southeast. Immediately to the south in the M-2 suite, the entire structural grain is rotated by tight folding and transposition into the east-west, second-generation trend. Farther to the south, in the Crab Hill suite, a third-generation foliation gradually becomes more prominent until the mesoscopic layering in these rocks is commonly a third-generation transposition of the second-generation layering. The map-scale structure, however, is still dominated by the second-generation structures. Further complications are added by the very local development of at least two other generations of minor structures. A swarm of small chevron folds in the western part of the Crab Hill suite are defined as F, structure, and very local development of small-scale, rounded folds in the M-2 suite are defined as F.: structures. The relative-age relationship between F, and F.,' structures is unknown as they do not overprint one another. The combination of F, and F: structures produces some spectacular small-scale interference effects at a few localities (fig. 8).

The overprinting of the various generations of structures produces an abundance of folds, foliations, and lineations. The various fabric elements observed are summarized in Table 1 and their relative orientations are shown in Figure 9.

Major Structure

Lenticular layering at all scales, produced by F, transposition, dominates the map patterns (figs. 3 and 10) and complicates delineation of stratigraphic units. There is no evidence of transposition produced during the formation of the earlier F, structure. In areas of transposition the overall orientation of original layering or stratigraphy is preserved only as enveloping surfaces to transposition lenses of a layer or stratigraphic unit. Such enveloping surfaces can be defined in the Pedernal area commonly on a mesoscopic scale (fig. 10), but the only two lithologies distinctive enough to be used in this way for stratigraphic interpretation are lenses of calc-silicate rocks and rhyodacite (fig. 3). The calc-silicates are in the Crab Hill suite and the dominance of the F, structures in outcrop complicates any interpretation. The rhyodacite

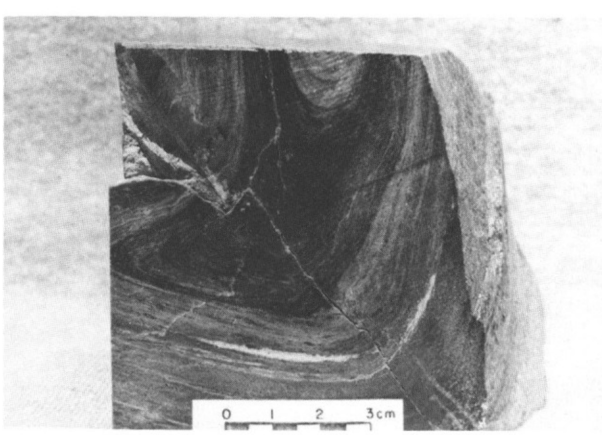

Figure 8. Small refolded fold formed by the interference of F_2 and F_4' folds.

Table 1. Structural fabric elements observed in Pedernal rocks.

	S_0	—Bedding in metasediments. Characterized by continuous bedding laminations and constant stratigraphic facing across outcrops.
F_1	S_1	—Slaty cleavage. Parallel to bedding in T-phase metasediments and as an earlier mica foliation crossing S_2 in thin sections of the other rocks.
F_2	S_2	—Slaty cleavage/crenulation cleavage/transposition foliation. In thin section the earlier foliation (S_1) is almost invariably present. In all rocks except T-phase metasediments, the lithologic layering parallel to S_2 is a transposition layering.
	L_{20}	—Intersection lineation of S_2 and S_0 defined by a prominent compositional striping. Parallel to F_2 folds in the original layering.
F_3	S_3	—Close spaced crenulation cleavage, accompanied by local transposition observed only in the Crab Hill rocks. Axial planar to small-scale isoclinal folds.
	L_{32}	—Intersection lineation of S_3 and S_2 defined by a prominent compositional striping. Parallel to F_3 folds in the S_2 transposition layering.
F_4	S_4	—Spaced crenulation cleavage dipping steeply SE. Axial planar to small, tight chevron folds in the Crab Hill rocks. Overprints S_3.
	L_{42}	—Crenulation lineation pitching steeply west in S_2.
	L_{43}	—Crenulation lineation pitching west in S_3.
	S_4'	—Spaced crenulation cleavage dipping shallowly SE. Axial planar to small, open rounded folds in the M-2 cycle volcanics. Only observed in the M-2 rocks. Time relationship to S_3 and S_4 unknown.

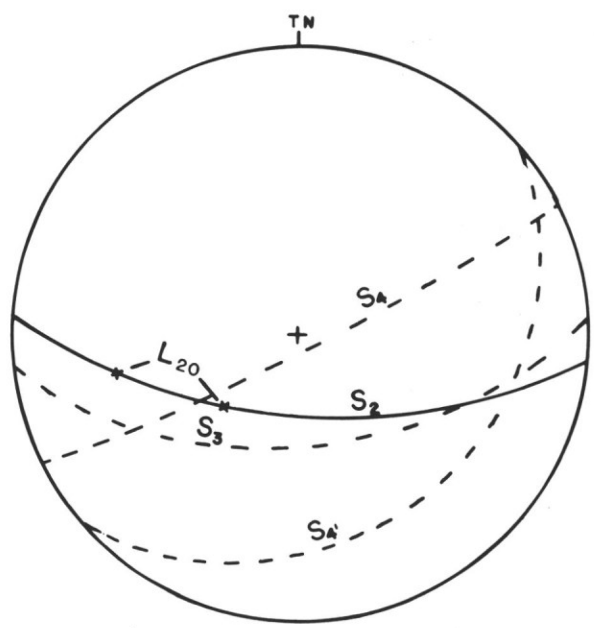

Figure 9. Equal-area stereographic projection showing modal orientations of observed structural fabric elements in the M-2 and Crab Hill suites. S_2 is a transposition layering and the earlier S_0/S_1 surfaces are only recognized locally in hinge areas. The two modal orientations of the prominent intersection lineation, L_{20}, are shown; all other observed intersection lineations defined in Table 1 occur at the appropriate intersection orientation.

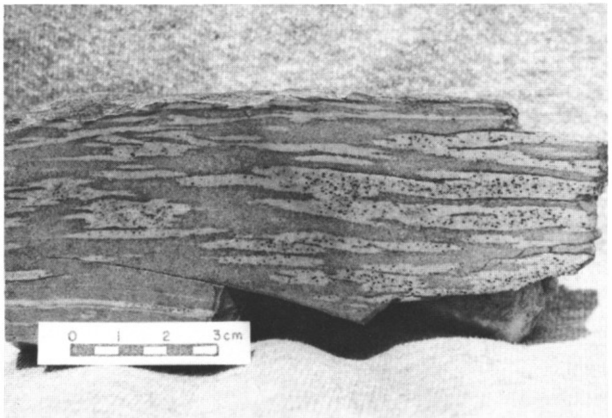

Figure 10. Lenticular layering formed by transposition. Small F_2 fold is defined by enveloping surfaces to transposition lenses of rhyodacite.

is in the M-2 suite, and its structure is dominated by only the first two deformations, making interpretation somewhat simpler.

The M-2 rhyodacite forms several large, irregular areas of outcrop (fig. 3), and it is suggested that the position and shape of these bodies is due to the interference pattern produced by the overprinting of large F_1 folds by large F_2 folds. The dominant F_2 transposition layering in the rhyodacites has a constant orientation, dipping at about 65° to the south (fig. 11). The lineation formed by the intersection of the original layering (S_0) and the S_2 foliation is a very prominent lineation on the S_2 surface. This L_{20} lineation is defined by a very distinctive compositional striping and is parallel to major F_2 folds developed in the original stratigraphy. The orientation of the L_{20} lineation is bimodal (fig. 11) and each mode corresponds to distinctive subareas on the ground (fig. 12). The subarea pattern defined by the L_{20} lineation and the general outcrop pattern of the rhyodacite is very similar to the theoretical pattern produced by the interference of two suitably oriented fold systems (Ramsay, 1967; see also fig. 13).

Figure 14 is a block diagram of the geometry of the rhyodacite body based on conclusions of the preceding paragraph. The bodies of rhyodacite previously presumed to be extrusive domes are interpreted as simple culminations in the fold interference pattern. There is further justification for this structural interpretation, in that the general trend

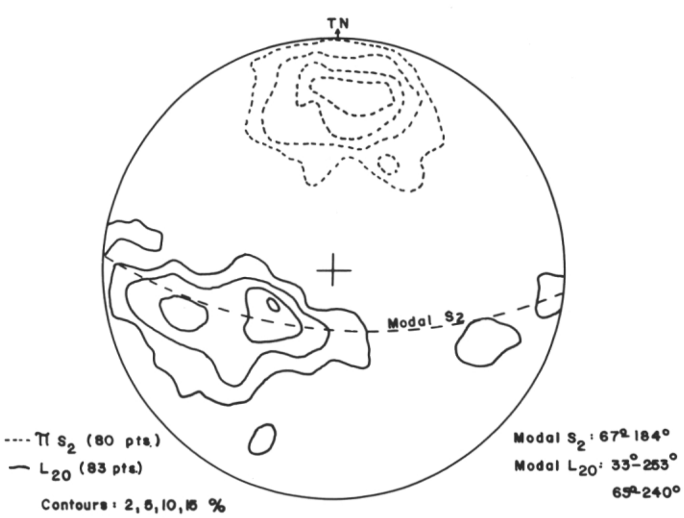

Figure 11. Equal-area stereographic projection of the L_{20} lineation and poles to the S_2 foliation. Note that the lineation forms a bimodal distribution with S_2.

of the first-generation axial planes is interpreted to be northerly or northeasterly rather than easterly, and this corresponds to the S_1 trend in the T-phase metasediments. Similarly, the interpreted wave length of the large F_1 folds in the rhyodacite is about the same as that in the T-phase metasediments. If the strike of S_1 in the metasediments can be taken as being more or less the original S_1 strike in the area, then the geometry of the F_1 folds can be interpreted (fig. 15). It is suggested that first-generation folds were overturned structures with axial planes dipping at about 60° to the northwest.

A further consequence of the structural interpretation shown by Figure 14 is that the overall stratigraphy in the area is dipping to the south. Perhaps it is also a southerly younging sequence, although little is known about the detailed boundary relationships of the major units.

Faulting

Post-Precambrian faults observed at the surface within the Precambrian core of the highlands are relatively uncommon. Those that were located show only minor strike-slip separation and no recognizable dip-slip component. Lateral extent on these faults is never more than 150 m. Identification of these minor fault zones is usually difficult unless breccias are seen. Offset of specific units within the metavolcanics is very common; however, these discontinuities are usually due to depositional or subsequent deformation effects.

The western limits of Precambrian rock are defined by a swarm of apparently normal faults with general north-south trends. These faults are not readily apparent at the surface. However, subsurface resistivity data leaves little doubt of their existence. The magnitude of the total swarm cannot be calculated from the data on hand, but individual vertical movement of approximately 400 m can be recognized for isolated faults within the swarm. The depth and extent of the Estancia basin would suggest that total vertical displacement along this zone should be in excess of 1,000 m.

DISCUSSION

As stated above, polyphase Precambrian deformation at Pedernal hinders the understanding of the protoenvironment. However, individual rock types can be considered as parts of major lithologic packages which can be assimilated into a reasonable original setting.

The M-2 volcanic suite and the T-phase suite probably represent part of a submarine volcanic field. Submarine deposition is substantiated by the abundance of elastic and precipitate sedimentary material. The fact that these sediments are so intimately interlayered with the volcanic assemblage therefore dictates that the volcanics also must have been deposited subaqueously. However, this does not necessarily eliminate a subaerial eruptive origin for at least part of the volcanic pile. The northern quartzite terrain and the Crab Hill suite also must have been deposited subaqueously. This environment differed, however, from that of the T-phase and M-2 environment in that the source rocks for the Crab Hill suite and the northern quartzite terrain were chemically very different. The northern quartzite terrain and Crab Hill suite were deposited much farther from their source than either the M-2 suite or the T-phase suite.

Table 2 shows chemical data (from x-ray fluorescence) from the M-2 and Crab Hill suites. These data indicate calc-alkaline affinities for the felsic and intermediate lithologies (fig. 16). Since there are only quartzites in the northern quartzite terrain (aside from minor meta-arkoses), it can only be said that this assemblage is part of a pelagic chert sequence that may or may not have any relation to the other rocks of the Pedernal Highlands.

The original depositional environment for the rocks at Pedernal was, perhaps, a small part of an island arc system. Further structural and chemical investigations of the entire Precambrian sequence at Pedernal would help test this hypothesis.

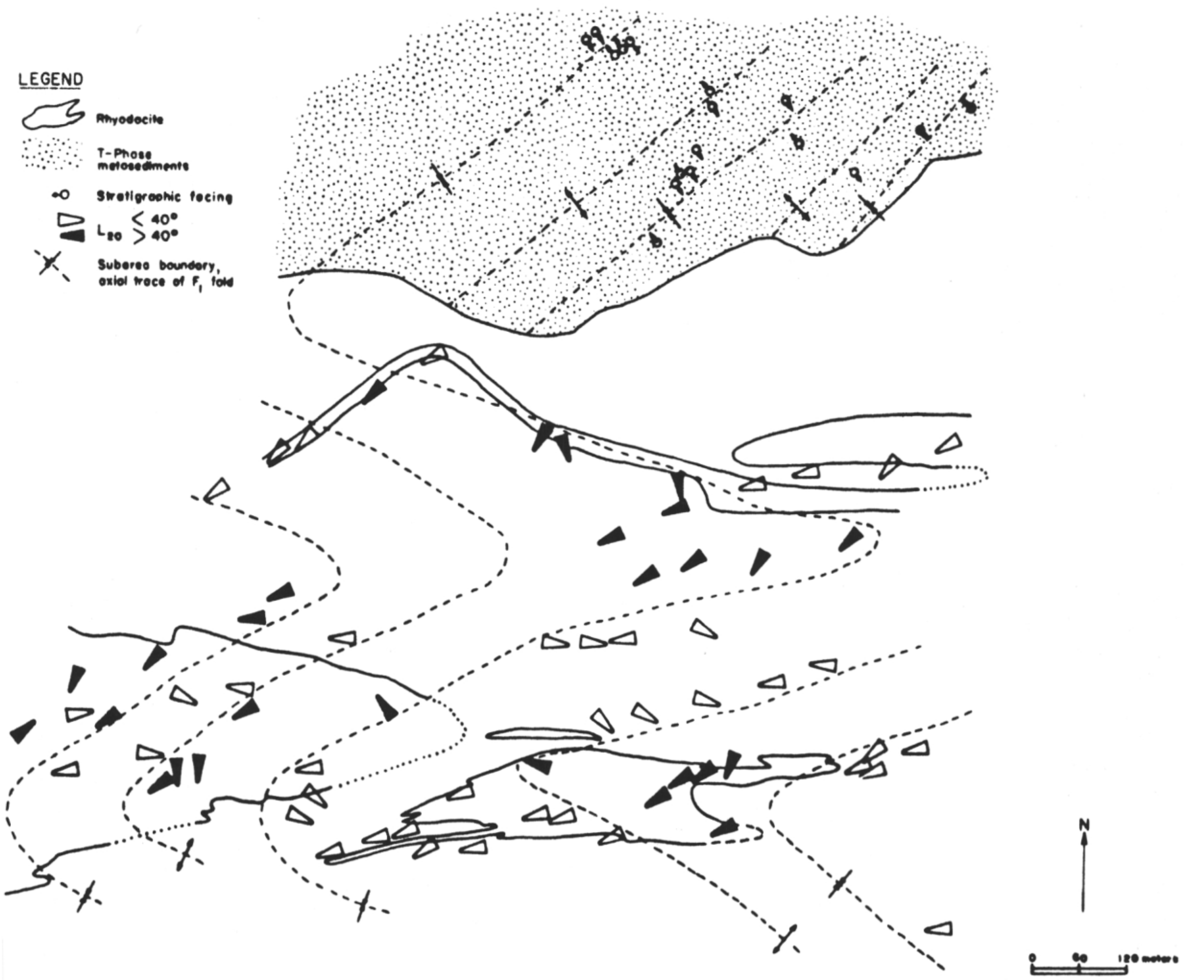

Figure 12. Map of the central part of the Pedernal area showing the outcrop distribution of rhyodacite in the M-2 suite and inferred sub-area boundaries based on orientation of the lineation L_{20}. The sub-area boundaries are inferred to correspond to the axial traces of F_1 folds. In the T-phase metasediments, these traces are defined by reversals in stratigraphic facing. The mapping precision of the northern strip of rhyodacite (in the center of the figure) is considerably less than that elsewhere, and the exact outcrop shape of this band of rhyodacite is unknown. Outcrop scarcity and recognition problems caused by transposition also place some uncertainty on the outcrop shapes shown for the southern rhyodacite bodies. It is probable that the boundary between the M-2 suite and the T-phase metasediments is a fault.

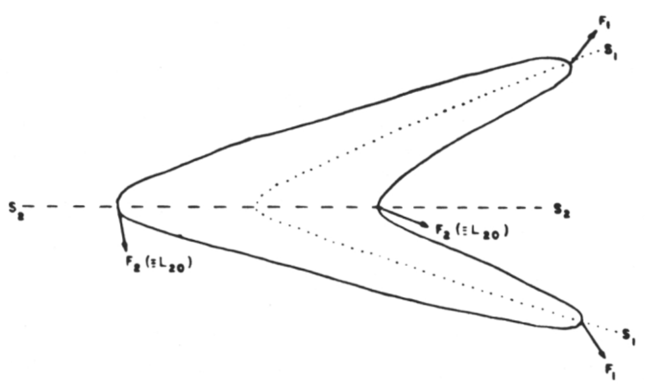

Figure 13. Theoretical boomerang-shaped outcrop pattern produced by the interference of suitably oriented first- and second-generation fold trains (Ramsay Type 2 interference pattern, see Ramsay, 1967, p. 527). The orientations of the two different F_2 fold hinges are determined by the intersection of the F_2 axial plane (S_2) and the original F_1 limb orientations. The boundary between the two different F_2 orientations is approximately the trace of the F_1 axial plane (S_1).

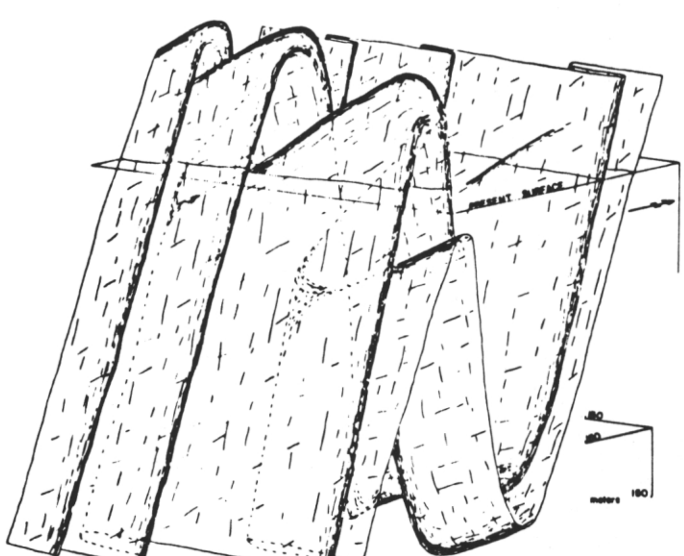

Figure 14. Orthographic block diagram showing inferred three-dimensional geometry of the upper surface of the rhyodacite shown in Figure 12.

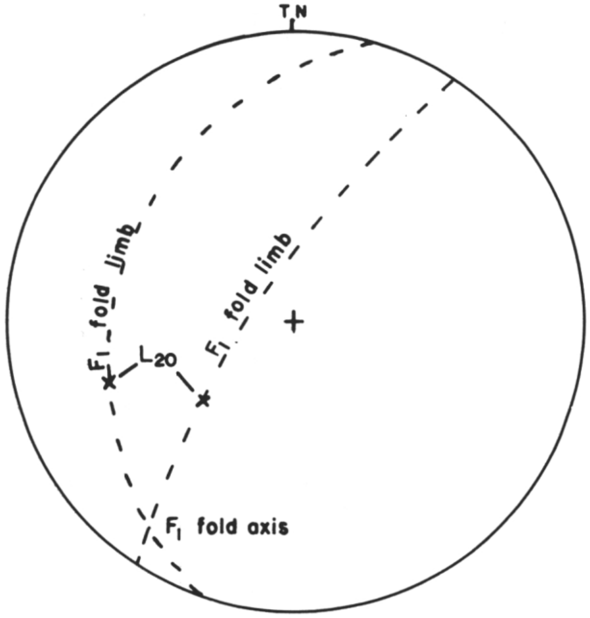

Figure 15. Equal-area stereographic projection showing the possible orientation of original F_1 folds, assuming that the strike of the F_1 axial plane is similar to the strike of S_1 in the T-phase metasediments, and that the folds have a southerly plunge in order to give an overall southerly younging to the sequence.

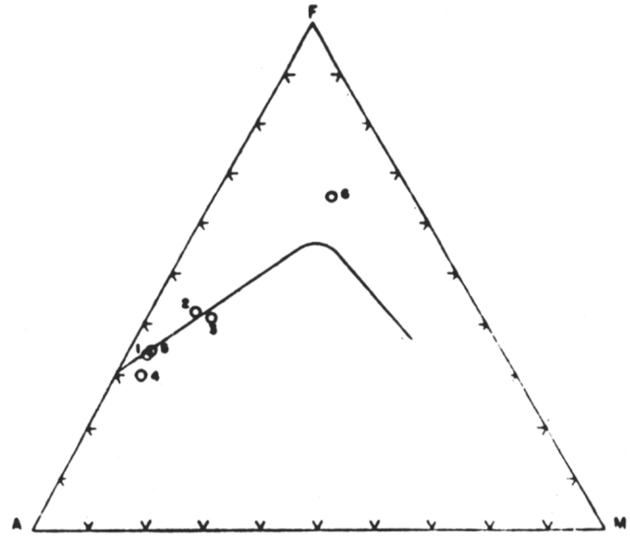

Figure 16. AFM diagram depicting the grouping of certain samples from both the M-2 and Crab Hill volcanic suites. The solid line represents the boundary between tholeiitic (upper region) and calc-alkalic (lower region) chemical fields (Irvine and Baragar, 1971). Samples 1 and 2 are M-2 felsics and 3 and 4 are Crab Hill felsics; while 5 is M-2 intermediate (altered), and 6 is from the Crab Hill mafic section.

Table 2. Chemical data from XRF analyses of samples from the M-2 and Crab Hill suites.

Sample No. —		(1) M-2 Felsic	(2) M-2 Felsic	(3) Crab Hill Felsic	(4) Crab Hill Felsic	(5) M-2 Intermediate (altered)	(6) Crab Hill Mafic
SiO_2	—	74.64	67.6	74.6	74.6	69.5	54.2
Al_2O_3	—	10.56	12.6	12.5	12.4	14.7	13.3
Fe_2O_3	—	2.00	2.51	2.25	2.0	2.25	4.05
FeO	—	2.86	4.59	2.25	1.7	2.25	11.2
MgO	—	0.4	1.2	1.1	0.5	.4	4.5
CaO	—	0.81	3.1	1.5	0.6	1.5	7.4
Na_2O	—	4.18	4.3	1.8	4.7	5.1	2.3
K_2O	—	4.00	3.4	2.9	2.9	2.1	0.9
TiO_2	—	0.18	0.5	0.5	0.3	.5	1.3
P_2O_5	—	0.06	0.14	0.12	0.09	.14	0.28
MnO	—	0.07	0.15	0.11	0.10	0.09	0.25
Total	—	100.39	100.09	99.63	99.89	98.53	99.68

ACKNOWLEDGMENTS

The authors wish to thank Conoco, Inc., a Dupont unit, for permission to publish this information. We would also like to acknowledge the work done by P. Merrick, A. K. Loring, and other Conoco geologists. The authors also wish to thank J. Callender for reviewing the manuscript and for his valued discussions, and J. Kingan for typing the numerous rough drafts and final manuscript.

REFERENCES

Fallis, J. F., Jr., 1958, Geology of the Pedernal Hills area, Torrance County, New Mexico (M.S. thesis): University of New Mexico, Albuquerque, 50 p.

Fisher, R. V., 1960, Classification of volcanic breccias: Geological Society of America Bulletin, v. 71, p. 973-982.

Gonzales, R. A., 1968, Petrography and structure of the Pedernal Hills, Torrance County, New Mexico (M.S. thesis): University of New Mexico, Albuquerque, 78 p.

Gonzales, R. A. and Woodward, L. A., 1972, Petrology and structure of the Pedernal Hills, Torrance County, New Mexico: New Mexico Geological Society Guidebook 23, p. 144-147.

Irvine, T. N. and Baragar, W. R. A., 1971, A guide to the chemical classification of the common volcanic rocks: Canadian Journal of Earth Sciences, v. 8, p. 523-545.

Loring, A. K. and Armstrong, D. G., 1980, Cambrian-Ordovician syenites of New Mexico, part of a regional alkalic intrusive episode: Geology, v. 8, p. 344-348.

Ramsay, J. G., 1967, Folding and fracturing of rocks: McGraw-Hill, New York, 568 p.

Sangster, D. F., 1972, Precambrian massive sulfide deposits in Canada: A review: Geological Survey of Canada Paper 72-22.

Woodward, L. A. and Fitzsimmons, F. P., 1967, Precambrian banded iron formation, Pedernal Peak, Torrance County, New Mexico (abstract): New Mexico Geological Society Guidebook 18, p. 228.