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STRATIGRAPHIC SUMMARY AND STRUCTURAL PROBLEMS OF PRECAMBRIAN ROCKS, PICURIS RANGE, NEW MEXICO

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INTRODUCTION

The Picuris Range, located in north-central New Mexico 20 km southwest of Taos (Fig. 1), is a Precambrian-cored projection pointing westward from the southern Sangre de Cristo Mountains. All of the Precambrian rocks in the range are of Proterozoic age. They are bounded on the east by Cenozoic and Paleozoic rocks, and on the other three sides by sediments of the Rio Grande rift and volcanic rocks of Tertiary age.

Mineral assemblages in the Proterozoic rocks indicate medium-grade (amphibolite facies) peak metamorphic conditions near 530°C, 3.7 kb (Holdaway, 1978), at or near the AI,SiO, triple point.

Several major stratigraphic and structural problems remain to be solved in the highly deformed Proterozoic rocks of the Picuris Range. This report discusses several of these problems.

PREVIOUS WORK

Two major groups of Proterozoic rocks are present in the Picuris Range and adjoining uplifts: a metamorphosed elastic sequence without significant volcanic rocks (Ortega Group), and a metamorphosed volcanic sequence (Vadito Group). There are two hypotheses concerning the relative age of these sequences in the Picuris Range. One holds that the Ortega Group is younger than the Vadito Group (Just, 1937; Gresens and Stensrud, 1974; Holcombe and Callender, 1982); the other maintains that the Vadito Group is younger than the Ortega Group (Montgomery, 1953; Nielsen, 1972; Long, 1976; Scott, 1980).

Although there has been considerable controversy over the stratigraphic sequence in the Precambrian rocks of northern New Mexico, the most recent work (Holcombe and Callender, 1982; Grambling and Codding, 1982; McCarty, 1983) has suggested that the Ortega rocks overlie the Vadito. Radiometric dates from rocks of the Truchas Range are consistent with this interpretation (Grambling, pers. comm. 1984).

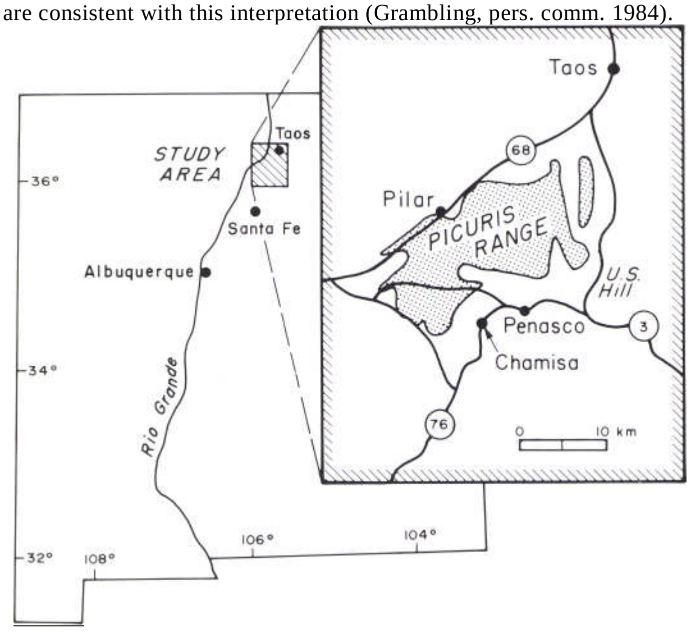

FIGURE 1. Location map showing the Picuris Range, New Mexico.

STRATIGRAPHY

The Proterozoic sequence in the Picuris Range consists of two thick, lithologically dissimilar sequences of rocks separated by a major fault (Fig. 2). The base of neither sequence is exposed. In the Picuris Range, the two groups may be separated by a fault-bounded slice of rock (the Piedra Lumbre Formation) that is not totally part of either group.

In the southern Picuris Range, the Vadito Group consists of a lower unit of interbedded amphibolites, metamorphosed volcaniclastic rocks, quartz—muscovite—biotite schists, and phyllites which are overlain by quartzites and conglomerates of the Marquenas Quartzite. Farther north lie fine-grained, banded, garnet—biotite—muscovite phyllites, metasiltstones, schists, and calc-silicates of the Piedra Lumbre Formation.

The Ortega Group consists of the massive, clean, crystalline Ortega Quartzite overlain by interbedded pelitic schists and quartzites of the Rinconada Formation, and by fine-grained, carbonaceous black slates and phyllites of the Pilar Phyllite. In the northern Picuris Range, above the Pilar, is a unit that resembles the Piedra Lumbre and is here informally called the schist of Hondo Canyon. The youngest Proterozoic rocks are coarse-grained quartz monzonite and granodiorite of the Embudo Granite, and coarse-grained granitic pegmatites.

Miller and others (1963) and Grambling and Codding (1982) have suggested correlations between Truchas and Rio Mora rock units and lithologically similar units in the Picuris. In the Truchas and Rio Mora areas, stratigraphy and geochronology suggest that Ortega is younger than Vadito. By inference this should also be true in the Picuris area. U—Pb zircon dates of about 1,700 m.y. for the felsic schist below the Ortega Quartzite (L. T. Silver, unpubl. data 1984) yield a maximum age for deposition of the Ortega Quartzite.

STRATIGRAPHIC PROBLEMS

Although Nielsen (1972) correlated the Piedra Lumbre Formation of the southern Picuris Range with the schist of Hondo Canyon in the northern Picuris Range, they differ in several aspects. Whereas the Piedra Lumbre Formation is mostly a fairly uniform fine-grained muscovite—biotite phyllite, the schist of Hondo Canyon additionally contains interlayered black-slate and black-phyllite horizons which range in thickness from a few to tens of meters, plus a significant thickness of light-colored, thinly bedded, micaceous quartzite near its base. The contact between Piral Phyllite and Piedra Lumbre in the southern Picuris Range is fairly abrupt, and is characterized by a strongly sheared phyllonitic zone. In contrast, the same contact in the northern Picuris Range is gradational, with various calc-silicate layers in the transitional zone rather than phyllites. These differences together with tentative structural differences (described below) indicate that either the Piedra Lumbre and Hondo Schist units are not correlative, or that the major fault described in the southern Picuris above the Pilar Formation does not exist above the Pilar in the northern Picuris. It seems appropriate to avoid applying the term Piedra Lumbre to these northern rocks until their relationship to the Piedra Lumbre at its type locality is better understood.

A second stratigraphic problem concerns the micaceous, quartz-rich rock that Montgomery (1953) termed the Rio Pueblo Schist. It is structurally below Ortega Quartzite in the Pilar area, and a similar rock occupies the same structural position near U.S. Hill. Gresens and Stensrud (1974) have argued that these rocks are metarhyolite sequences upon which the Ortega Quartzite was deposited. If so, then that contact may separate a major metasedimentary terrane (the Ortega Group) from

GROUP	FORMATION	MEMBER	LITHOLOGY	THICKNESS[1] (m)	YOUNGING[2]
	Pegmatites		Coarse-grained granitic pegmatites.		
Embudo Granite	Penasco Quartz Monzonite Rana Quartz Monzonite Puntiagudo Gran. Porphyry Cerro Alto Metadacite		Variable, but generally coarse-grained, microcline-rich, quartz monzonites to granodiorites. (See Long, 1976).		
?	Hondo Schist[3]		Interbedded, banded, garnet-staurolite schists and metasiltstones; calc-silicates; amphibolites and black slates locally.		↑
-?-?-?-	Pilar Phyllite		Black slate and fine-grained phyllite with iron-oxide stains and local white schist beds; Distinctive basal blue-black garnet quartzite. (see Montgomery, 1953).	84 (N)	
Ortega Group	Rinconada[4] (see Montgomery, 1953)	R_6 Rs_3	Banded gray to red quartz-muscovite-biotite-garnet phyllite and schist. Strongly crenulated.	240–565 (M) 350 (N)	YOUNGING
		R_5 Rq_2	Massive, micaceous, white to gray quartzite grading up to massive, blue crystalline quartzite.		
		R_4 Rs_2	Reddish weathering gray schist with small euhedral garnets and staurolites. Local staurolite phyllite.		
		R_3 Rq_1	Tan to white, micaceous, cross-bedded quartzite grading up to massive, crystalline, blue quartzite.		
		R_2 Rs_1	Muscovite-staurolite schist with large twinned staurolites.		
		R_1	Biotite-muscovite-andalusite "salt and pepper" schist.		
	Ortega Quartzite		Massive, clean, coarsely crystalline, white to gray to yellow brown, cross-bedded quartzite; local interlayered aluminous schists. (See Montgomery, 1953).	760 (M) 835 (N)	
Felsic metavolcanic-metasedimentary complex (includes the Rio Pueblo Schist).			Metarhyolite, metasediments, red-mica schist, metaconglomerate. (see Gresens and Stensrud, 1974).	Base Unexposed	
?	Piedra Lumbre[5]		Fine-grained, carbonaceous, muscovite-biotite phyllite with garnet porphyroblasts; local calc-silicates. Internally transposed. (See Montgomery, 1953).	183 (N) 369 (L)	↑
-?-?-?-	Marquenas Quartzite (see Scott, 1980)	Mc_1	Conglomerate with deformed quartzite pebbles in a micaceous quartz matrix. "Flaser" structures.	610 (M) 410 (L)	YOUNGING
Vadito Group		Mrq	Cross-laminated, rippled, micaceous quartzite with isolated pebble layers.		
		Mq	Sparsely cross-bedded, vitreous, massive gray quartzite with pebble layers.		
		Mc_2	Quartzite, felsite, and mafic pebble conglomerate with micaceous quartzite matrix.		
	Vadito Schist		Various quartz-muscovite schists and phyllites with interbedded mafic metavolcanics. (See McCarty, 1983).	760 (M) 700 (L)	
	Vadito Amphibolite		Various mafic metavolcanics with interlayered metaclastics and metavolcaniclastics. (See McCarty, 1983).	Base Unexposed	

1 (M) = Montgomery, 1953; (N) = Nielsen, 1972; (L) = Long, 1976

2 Relative ages of Ortega and Vadito Groups based partially on criteria in Rio Mora area by Grambling and Codding, 1982; and Grambling, 1983.

3 The Hondo Schist is recognized in the northern Picuris only, and may be correlative with the Piedra Lumbre Formation.

4 According to Grambling (pers. commun., 1984) the R_1-R_2 mineralogical change is metamorphic rather than original sedimentary, thus the Rs-Rq system is preferred.

5 In the southern Picuris, the Piedra Lumbre - Pilar contact is a major fault (Holcombe and Callender, 1982). If the Hondo Schist is equivalent or partially equivalent to the Piedra Lumbre, then the Marquenas - Piedra Lumbre contact must also be a major fault.

FIGURE 2. Lithologic column for Precambrian rocks of the Picuris Range, New Mexico.

an underlying metavolcanic terrane (the Vadito Group). Grambling an(others (1983) recognized a viridine-bearing (Mn-rich andalusite) ho rizon which defines the contact between the Ortega Group and thy underlying Vadito Group in the Rio Mora area, the Truchas Peak region, and the western Picuris Range near the town of Pilar. William and Wobus (1984) have identified the same marker horizon in basa Ortega Quartzite throughout the Tusas Range. Viridine has been fowl(near the base of the Ortega Quartzite during recent mapping near U.S Hill in the eastern Picuris Range. The presence of this unusual, perhap time-stratigraphic, horizon establishes a firm stratigraphic correlatioi between uplifts across north-central New Mexico.

STRUCTURE

The dominant east—west fabric of the Picuris Range is due to a se of large-scale, cast- to east—northeast-trending, tight to isoclinal fold overturned to the north (Montgomery, 1953). The major folds are thy Copper Hill anticline to the south and the Hondo syncline to the nortl (Fig. 3). These folds are cut by three generations of faults (Nielsen am Scott, 1979), from oldest to youngest (1) shear zones subparallel t(axial surfaces of major folds, (2) oblique-slip faults which trend eithe northeast—southwest or northwest—southeast (e.g., the Pilar—Vadito fan! of Montgomery, 1953), and (3) normal faults of late Tertiary age.

Structural-fabric Elements

Deformational fabrics have been defined on the basis of detaile(mapping and structural and thin-section analyses of rocks in the norther! Picuris Range, in an area that includes both limbs of the Hondo syncline The terms discussed below are defined in Holcombe and Callende (1982).

Folding events are denoted F, and F„ with associated axial plan(cleavages S, and S,. L_o and L_{20} are intersection lineations of surface designated by subscripts. In most rocks compositional layering is though to represent true stratigraphic bedding (S_o) due to well-preserved sed imentary structures within layering. S,, the earliest cleavage, appear as a schistosity in micaceous rocks of the Vadito Group in the southen Picuris Range (Holcombe and Callender, 1982). S, is generally paralle to bedding (S_o), thus S_o and S, will be included together as So/S,. S2 is the second-generation penetrative cleavage and appears to be dominant in both the southern and northern Picuris Range schistose rocks.

This study has identified a persistent schistosity generally parallel or subparallel to compositional layering (S_o). In most samples this schistosity is the only cleavage present. In several samples collected from fold noses, in which the schistosity is axial planar to the fold, it appears that only compositional layering is folded. This suggests that the schistosity is S, and cuts bedding in F, folds. However, if this fabric is S,, one would expect to see the more dominant S, cleavage superimposed on it. In fact, only one thin section shows convincing evidence for both S, and S,. In this sample, from a quartz—mica schist of the Rinconada Formation, S, appears as oriented micas in quartz-rich layers of S, differentiated layers (Fig. 4). The appearance of S,—S, relationships such as this, in which a segregated S, crenulation-cleavage folds an earlier S, schistosity, is highly dependent on the quartz/mica ratio of the schist. A ratio close to 50/50 is most conducive to the visibility of both S, and S,. This overprint geometry has commonly been described in Proterozoic rocks of northern New Mexico (Codding, 1983; McCarty, 1983). It is not known whether this sample is representative of the area and both S, and S, exist in these rocks, or whether the sample is atypical and there is only one penetrative cleavage. Holcombe and Callender (1982) noted that although both S, and S, were recognized in Piedra Lumbre and Vadito Group rocks, S, was not positively identifiable in the Rinconada Formation or Pilar Phyllite in their study area. It is possible that in most samples of Ortega Group rock both S, and S, do not appear together because either S, has obliterated S, or the quartz/ mica ratio was not appropriate for the mutual development of S, and S,. Alternatively, the sample may be a special case and either S, or S, is not developed in the northern Picuris Range.

Both S_o/S, and S, are locally overprinted by several less pervasive, weak crenulation cleavages (S,). The various S, cleavages are difficult to separate and are not considered important in the deformational geometry.

It is generally impossible to distinguish S, and S2 in outcrop. Compositional layering (S_o) is cut by a subparallel axial-plane cleavage (S2).

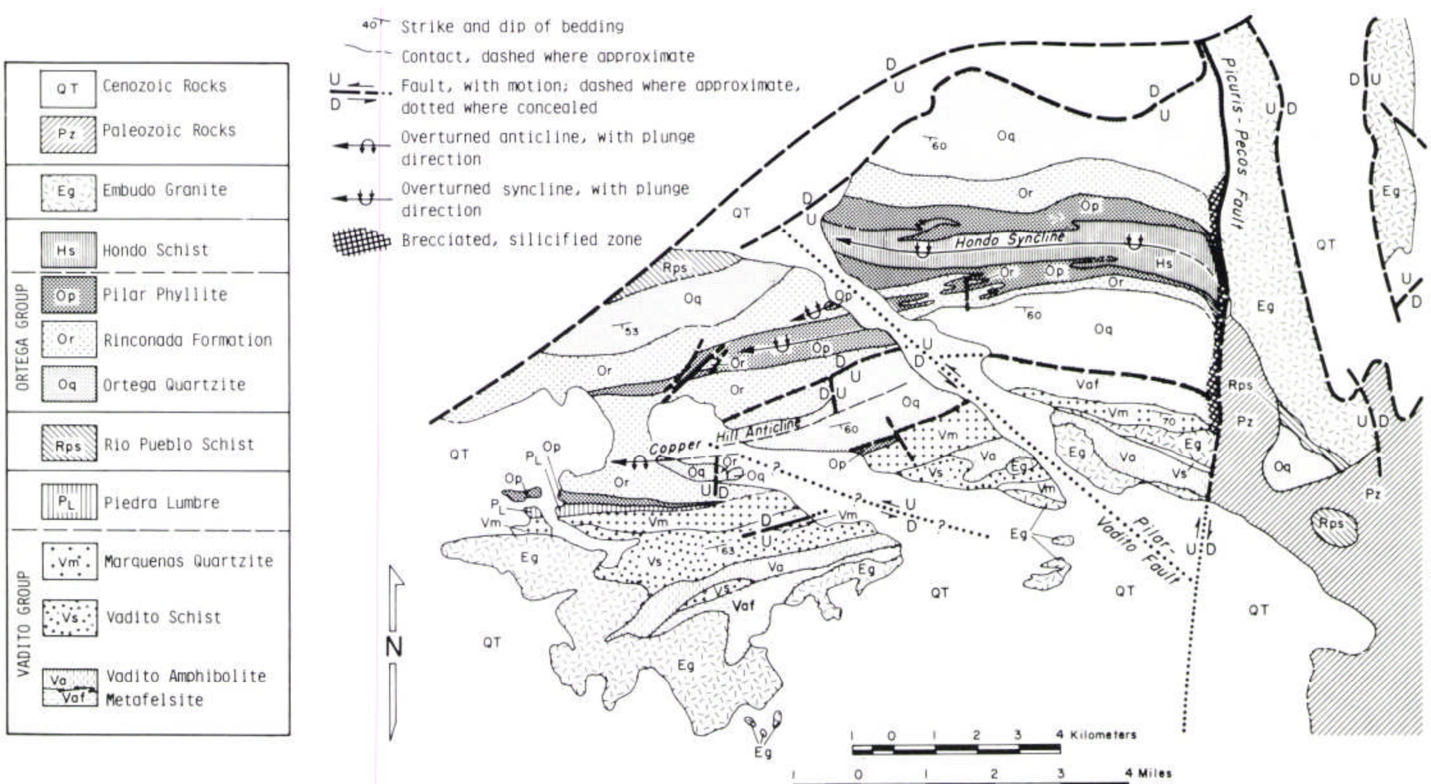

FIGURE 3. Generalized geologic map of Precambrian rocks of the Picuris Range, New Mexico. After Montgomery (1953), Nielsen (1972), and Williams (1982).

FIGURE 4. Photomicrograph of a schist of the Rinconada Formation, northern Picuris Range, showing the orientations and overprinting relationships of S_1 and S_2 cleavages. S_1 appears as scattered micas in quartz-rich S_2 layers. Field of view is 3 mm across.

There are two ways of approaching the problem of S,—S,. The first method is based on work by Holcombe (pers. comm. 1983) in which he has tentatively recognized a correlation between stratigraphy. deformation, and porphyroblast growth in schists of the Picuris Range. Holcombe found that not only does the appearance of axial-plane cleavages depend on stratigraphic/geographic position, but that the growth of certain metamorphic minerals can be related temporally to cleavage formation. The second approach is through a study of folding and refolding within the area.

Folds

Folds in the Picuris Range vary in size from the Copper Hill anticline—Hondo syncline with wavelengths of 4 or 5 km to folds only millimeters across. A complete description of various fold types was given by Nielsen (1972). Nielsen believed that extremely large isoclinal F, folds (so large that the entire Picuris Range may be on one limb) were in turn tightly folded by east—west-trending folds coaxial with F, (i.e., the Copper Hill anticline and Hondo syncline) whose axial planes dip steeply south. These F, folds were later broadly cross-folded by F„ forming the present outcrop pattern of gentle, doubly plunging structures shown by Montgomery (1953) and Nielsen (1972).

This sequence of folding is consistent with descriptions of structures elsewhere in northern New Mexico. In the Rio Mora area, Grambling and Codding (1982; pers. comm. 1983) have described several map-scale isoclinal F, folds refolded by nearly upright, tight F, folds, plus rare S, crenulations. In the Tusas Mountains, M. L. Williams (pers. comm. 1984) has recognized a set of large, tight, upright F, folds with wavelengths of about 1 km, which locally fold a pre-existing layer-parallel cleavage (S,); both are cut by several later F, crenulations.

In the northern Picuris Range both limbs of the Hondo syncline dip about 55° to the south. Because this and many minor folds are very tight, one cannot say whether S, or S, is axial planar to those folds. One way to approach this problem is to look at refolding patterns.

Refolding

Although most workers agree that the Picuris rocks have experienced multiple deformations, the absence of map-scale refolded fold patterns (other than those formed by minor F, structures) in the Ortega Group is puzzling. Montgomery (1953) mapped one very small type-III fold (Ramsay, 1967) closure on the southern limb of the Hondo syncline in the northern Picuris, but the structure does not appear on the map by Nielsen (1972). Exposure is very poor in this area. Recent mapping there yielded no convincing evidence of F, fold closure, although a detailed structural survey in the northern Picuris has revealed that refolding does occur on a scale of less than 100 m. In several places it was found that S,/S,—S, structural vergence and stratigraphic facing disagreed. That is, older units were found to core F, synforms and younger units cored antiforms, thus forming synformal anticlines and antiformal synclines (Fig. 5). The small distances between these reversals imply that at least one of the two folds involved has a wavelength on a scale of tens of meters. These small folds do not seem to interfere greatly with the larger-scale folds that form the Hondo syncline. The interference pattern is probably between minor F, folds and minor F_2 folds. If the major F, folds are enormous, it is not clear why two relatively small sizes of parasitic folds (centimeters and tens of meters in wavelength) but none of intermediate map-scale size folds would appear, unless either F, formed shear zones rather than large folds, or F, and F, were coaxial so that local reversals in structural vergence and stratigraphic facing are the only evidence of refolding.

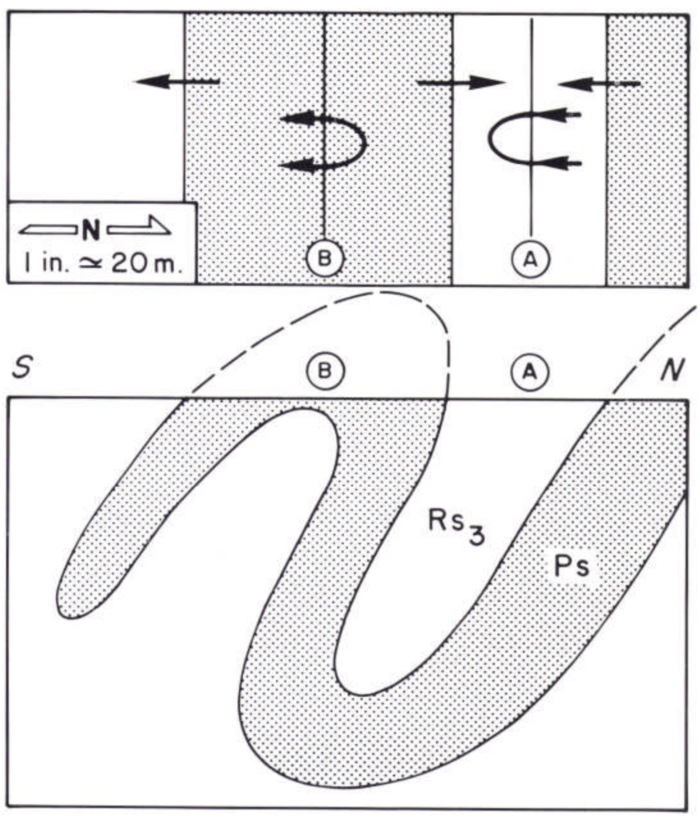

FIGURE 5. Idealized sketch map and cross section showing one possible refolded fold geometry for the Tierra Amarilla Canyon area, northern Picuris Range. Arrows on map point in the direction of synform. The older Rs_3 unit (Rinconada Schist) cores synforms; the younger Ps (Pilar Phyllite) cores antiforms, thus forming synformal anticlines and antiformal synclines.

Shear

Shear fabrics are common in quartzites of the Picuris Range. In the northern Picuris Range parallel elongate quartz grains commonly show a preferred crystallographic orientation along with sweeping extinction and strain ribbons. In one area on the north limb of the Hondo syncline the R_5 quartzite (Fig. 2) exhibits an extreme mylonitic texture (Fig. 6). It is not yet known if this outcrop represents a local zone or is part of a larger shear zone. Holcombe (pers. comm. 1983) has recognized a complex, anastomosing set of minor S_2-related ductile-shear zones (less than 1 m across) within the Embudo Granite in the southern Picuris Range. Callender and Holcombe (pers. comm. 1983) have speculated that thin, micaceous layers within the Ortega Quartzite and underlying metarhyolites in the Pilar area may be local areas of high-shear strain. It is not yet known whether ductile-shear zones make up a significant part of the deformation of the Picuris Range, nor whether major zones of ductile shear exist there at all. An interesting speculation is that F_1 deformation had a major component of subhorizontal shear and the S_1 fabric was well developed in local shear zones only. It is possible that this localized shearing was responsible for the destruction of all large F_1 fold noses.

STRUCTURAL ANALYSIS

I have made several preliminary structural analyses designed to detect both geographic and stratigraphic structural variations within rocks of the northern Picuris Range. In terms of geographic variations, no significant changes in S_0/S_1, S_2, and L_{20} appeared from the north to the south limb nor from the east to the west along the axis of the Hondo syncline. Local areas of anomalous fold axis and S-plane orientations are attributed to effects of broad F_3 folding and Phanerozoic faulting. However, in terms of stratigraphic variations of particular interest is an analysis of S_0/S_1, S_2, and L_{20} for Ortega Group rocks versus the schist of the Hondo Canyon. In the southern Picuris Range, Holcombe and Callender (1982) identified a strong S_1 in schists of the Piedra Lumbre Formation, but found no definite **S_1** cleavage in Rinconada Schist and Pilar Phyllite. Furthermore, they documented a change in both vergence and L_{20} orientation between the Pilar and Piedra Lumbre, and established that the Piedra Lumbre is internally transposed. They proposed that the S_0/S_1—S_2 vergence change across the Pilar—Piedra Lumbre contact is probably due to a single S_2 having been superimposed on slightly discordant S_1 planes across a boundary fault. It is therefore crucial for an understanding of the Piedra Lumbre—Hondo Schist situation to examine S_0/S_1—S_2 relations between these rocks in the northern Picuris Range.

Stereograms for the fabric elements S_0/S_1, S_2, and L_{20} in the Ortega Group (Ortega Quartzite, Rinconada Formation, Pilar Phyllite) and the Hondo Schist (Piedra Lumbre of Nielsen, 1972) are shown in Figure 7. Both F_3 deformation, and refraction and fanning of S_1 and S_2 cleavages are probably responsible for much of the scatter of points. S_0/S_1 and S_2 for both rock sequences have about the same east—west strike. The only significant variation in their dips is that S_0/S_1 for the Hondo Schist dips about 10° steeper than does the 55° dip of the other S_0/S_1 and S_2 planes. This 10° variation in S_0/S_1 may represent an original S_0/S_1 orientation difference between the two groups, but is not large enough to rule out errors in measurement or variations due to cleavage refraction. The most conspicuous difference between these data and those of Holcombe and Callender (1982) is in the orientations of L_{20}. Here both groups show similar southwest plunging statistical L_{20} maxima (Ortega at 239, 37°; Hondo at 247, 32°), although the Hondo Schists show a southeast plunging group at 120, 30° that is absent in Ortega rocks. Holcombe and Callender (1982) found that L_{20} for Ortega Group rocks plunged southwest, whereas L_{20} plunged southeast for Vadito Group rocks.

Although the data set is not shown, L_{30} and L_{32} intersection lineations define a fairly consistent orientation of 55° to the south, indicated by L_3 on the summary stereoplot of Figure 7.

Results suggest that if there is an early S_0/S_1 structural disparity between the Ortega and Hondo Schists, the disparity is too small to detect within the analytical error of measurements. S_2 fabrics appear to have been imposed identically over the two rock groups, suggesting that if their boundary is a fault, the major motion occurred prior to F_2 deformation. Both groups show similar southwest-plunging L_{20} patterns, although a southeast-plunging trend in the Hondo Schists may be related to an undocumented but possible S_0/S_1 disparity.

FIGURE 6. Photomicrograph of mylonite containing strained porphyroclasts, from R_5 quartzite north of the schist of Hondo Canyon. Field of view is 3 mm across.

SUMMARY AND CONCLUSIONS

It is not yet clear whether there are two regional, penetrative, axial-plane cleavages (S_1 and S_2) in the Precambrian rocks of the northern Picuris Range. The existence of two cleavages is suggested by a single thin section showing an S_1—S_2 microfabric relationship, and by structural-vergence measurements in the field which imply refolded folding. The style of F_1 deformation is unclear; no map-scale F_1 folds have been recognized, but minor F_1 folds or shear zones do exist. One possibility is that F_1 deformation is concentrated along shear zones and S_1 is thus localized. F_2 has formed tight, gently plunging folds overturned to the north and a strong, penetrative axial-plane cleavage (S_2), which are the dominant structural features in the northern Picuris Range.

The Hondo Schist may or may not be stratigraphically equivalent to the Piedra Lumbre Formation of the southern Picuris. Although the Piedra Lumbre seems to have been deformed during F_1 along with the Vadito Group, it is likely that the Piedra Lumbre is in fault contact with both the Ortega and Vadito Groups and that the faulting predated, or was concurrent with, F_1 deformation. A preliminary structural analysis comparing the fabrics of the schist of Hondo Canyon with Ortega rocks has shown that the only structural difference between them is a 10° difference in the dips of modal S_0/S_1. This variation may be within analytical error, and, therefore, does not unequivocally demonstrate pre-F_2 difference between these two rock groups. If the contact between the Pilar Phyllite and the schist of Hondo Canyon is not a fault, and the schist of Hondo Canyon is equivalent to the Piedra Lumbre For-

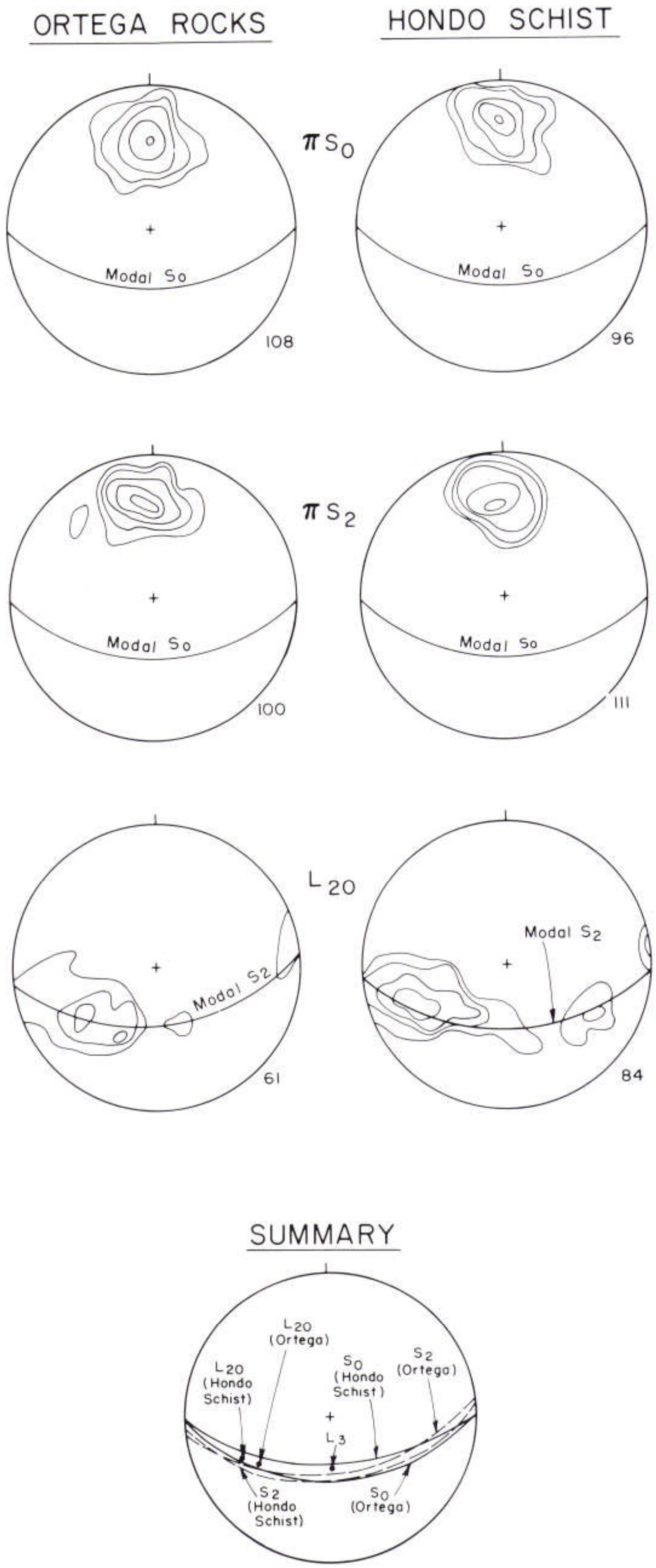

FIGURE 7. Stereograms showing the orientations of the major structural-fabric elements of the Ortega Group (Ortega Quartzite, Rinconada Formation, and Pilar Phyllite) and the Hondo Schist. Lower hemisphere, equal-area projections, tic to true north. Contours are at 2%, 4%, 8%, and 24% per 1% area, with the 1% contour added to both L_{20} plots. The number of data points is given at the lower right of each stereogram.

mation, then the schist of Hondo Canyon is a more complete section than the Piedra Lumbre in the southern Picuris Range. However, until more work is done in and around the schist of Hondo Canyon, it seems preferable to keep the schist of Hondo Canyon separate from the Piedra Lumbre Formation, the Vadito Group, and the Ortega Group.

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