PALEOZOIC DEFORMATION OF THE CHUACÚS GROUP IN THE SIERRA DE LAS MINAS RANGE, GUATEMALA

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ABSTRACT

At least three phases of approximately co-axial folding have been recognized in the southwestern end of the Sierra de las Minas range in Guatemala. F_1 isoclines are subhorizontal, F_2 folds are predominately overturned to the south, and F_3 is represented by open flexural-slip folds. Textural studies indicate that no significant recrystallization occurred during F_2 or F_3, suggesting that F_1, F_2, and F_3 represent three pulses of one orogenic event which probably occurred during the middle Paleozoic. Horizontal displacement by F_1 folding was greater than 1 mile, and therefore qualifies this structure as a nappe. This type of structure has been recognized along approximately 90 km. of the Sierra de las Minas range, suggesting that much, if not all, of the southern portion of this mountain range is an east-west trending refolded nappe.

INTRODUCTION

The purpose of this paper is to outline the nature and tectonic significance of Paleozoic deformation in the Chuacús Group in the southwestern part of the Sierra de las Minas range in Guatemala. Subsequent late Mesozoic and Tertiary tectonism of these rocks is beyond the scope of this report. However, it is necessary to be able to understand ancient structures in order to distinguish more clearly later structural events that are superimposed on these rocks.

King (1959) noted that the north-south trending Cordilleran orogen in western North America extends southward into Mexico. Burchfiel and Davis (1972; 1975) suggested that this trend may be partially disrupted by faulting in northern Mexico and Southern California. However, King (1959) and Kesler (1971) have shown that, near the border between Mexico and Guatemala, the Central American Cordillera makes a sharp eastward bend, and crosses Guatemala in an east-west direction, terminating in British Honduras, rather than continuing southeastwardly down the west side of Central America (Fig. 1). These ranges are characterized by complex metamorphic assemblages of pre-late Paleozoic rocks.

The location of the study area (Fig. 1 and 2) is in El Progreso quadrangle on the southwestern side of the Sierra de las Minas range. Earlier reconnaissance studies in this vicinity by McBirney (1963) and Bosc (1971), unpublished) had significant discrepancies between them. These conflicting views justified a re-evaluation of this region in 1971 by the author. In addition to this study Newcomb (1975) mapped the San Agustín Acasaguastlán quadrangle to the east of El Progreso and the Río Hondo quadrangle to the northeast of the San Agustín quadrangle along the southern side of the Sierra de las Minas range. These studies indicate that this mountain system is composed chiefly of a complex group of metasedimentary and metaigneous rocks which are collectivel known as the Chuacús Group.

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The age of the Chuacús Group is not firmly established. Structurally it lies below the Santa Rosa formation which is pre-Cretaceous, and may be Pennsylvanian in age according to McBirney (1963). However, even this age is open to question (Walper, 1960; Clemons and others, 1974). Radiogenic ages determined from these rocks by Pushkar (1968), Gomberg and others (1968), and McBirney and Bass (1969) suggest that three metamorphic events may have affected these rocks at: 1) 1,075 m.y., 2) 345-386 m.y., 3) 66 m.y. Roper (1973) and Newcomb (1975) suggested that the most recent date might be related to faulting and/or recrystallization and metasomatism associated with serpentinite emplacement along the Motagua fault zone. The oldest date was determined from zircons which show some evidence of recrystallization, suggesting that it represents either the first metamorphic event or detrital zircon from an older rock (Gomberg and others, 1968). Thus, the age of the Chuacús Group is uncertain and could be either Precambrian or middle Paleozoic.

STRUCTURAL RELATIONSHIPS IN THE CHUACÚS GROUP

Mesoscopic fabric analyses indicate that the Chuacús Group experienced at least three phases of pre-Mesozoic deformation. The earliest recognized foliation in these rocks is designated S_1 and is characterized by schistosity and gneissic foliation found in the mica schist and gneiss. Locally, schistosity and gneissic foliation may alternate in an outcrop, producing compositional layering which is presumed to parallel intensely transposed sedimentary bedding S_0. S_1 consists of an axial plane foliation related to F_1 folds. Poles to S_1 foliation are plotted in a π-diagram (Fig. 3a); their distribution forms a broad irregular girdle along a major meridian. Such a distribution pattern is generally interpreted as indicating cylindrical folds (Turner and Weiss, 1963). The broadness and irregularity of this fabric pattern along a major girdle is probably due to the small number of data points and superimposition of later stages of folding on this early foliation.

The first generation of folds, F_1, produced S_1 compositional layering and axial plane foliation which are characterized by sub-horizontal passive slip and flow isoclines. F_1 folds are rarely observed in the mesoscopic scale, and when found, are usually in steep two-dimensional outcrops (Fig. 4) which do not permit direct measurement of their axial directions. As a result, the bearing of only one F_1 fold axis was measured. Its axial trend is S43W, plunging 6 degrees to the southwest (Fig. 3b) with an axial plane dipping 20 degrees to the northwest (Fig. 3c). No definite conclusions can be made about the orientation of this fold system from only one measurement. However, it is believed that this bearing may reflect the general trend of F_1 folds based on the following evidence: 1) All F_1 folds were observed on north trending road cuts or canyon walls, suggesting that they have a northeasterly or easterly trend. 2) Newcomb (1975) also recognized F_1 folds farther to the northeast in the Río Hondo quadrangle with trends and geometries similar to those described here, although their axial trends plunge more steeply and strike more E-W than those in El Progreso. 3) Where F_1 folds were observed in direct relationship with F_2 folds in two-dimensional outcrops, they appear to be approximately co-axial with F_2 folds. 4) The latter relationship is also suggested on the plot of the F_1 fold axis which roughly coincides with the direction of F_2 fold axes (Fig. 3b). 5) Poles to S_1 foliation in Fig. 3a form a broad merdianal girdle with a secondary point maximum that could be interpreted as representing the orientation of limbs of isoclines. Geometrically, a plane bisecting these maxima should approximate the axial plane of F_1 isoclines. The attitude of this plane is estimated at N45E, 40 NW which is in reasonably good agreement with the measured F_1 axis and axial surface. Therefore, it is suggested that F_1 fold axes may be approximately co-axial with F_2 folds, and therefore trend in a northeast-southwest direction near El Progreso, but may become oriented in a more east-west direction farther to the northeast. S_1 axial plane foliations, several kilometers north of the Motagua fault zone, are generally subhorizontal with moderate dips to both the north and south due to subsequent deformations that have refolded this surface. However, with increased proximity to the Motagua fault zone, particularly within Chuacús lithologies in the eastern part of the quadrangle, the S_1

foliation dips predominantly to the south suggesting that either the hinge or root zone of the F_1 fold system dips into what is now the Motagua fault zone.

S_1 foliation was refolded during the F_2 deformation, producing overturned to isoclinal passive slip folds. The attitudes of axial planes in F_2 folds are illustrated in Fig. 3c and indicate that almost all of these folds are overturned to the south. One large, overturned to the south F_2 fold was observed which has an amplitude of at least several hundred feet (Fig. 5). F_2 folding attenuated S_1 foliation along the limbs, and produced S_2 slip-cleavage in the hinges of these structures. The crest of S_2 slip-cleavage forms a lineation which parallels the hinges of F_2 folds (Fig. 3d).

Axial trends of F_2 folds illustrated in Fig. 3b are somewhat scattered, but show a definite trend plunging gently in the direction of S70W. Figure 3b indicates that several folds with this kind of geometry, and refolded foliations in their hinges, trend northwest or southeast. These discrepancies in orientation may be attributed to one or a combination of causes. First, they may reflect disharmonic folding during the second deformation. Second, they may indicate reorientation due to subsequent refolding. Finally, they may be due to a separate deformation with a different strain direction, which may have occurred at a later date, perhaps even as recently as the Mesozoic. Unfortunately, not enough of these folds were recognized during mapping to provide sufficient information to distinguish which of the above possibilities is the best interpretation.

F_3 folding is characterized by open flexural-slip folds. Figure 3b illustrates the axial trend of these folds, and indicates that they are approximately coaxial with F_2 folds. This is also seen in outcrop (Fig. 5). Axial planes of F_3 folds are inclined to both the north and south (Fig. 3c). Some of this range in pattern is also illustrated in Fig. 5 which suggest that F_3 folds are drag folds superimposed on F_2 folds. Such a relationship would account for the parallelism between F_2 and F_3 fold axes, and the radial pattern of F_3 axial planes with respect to F_2 axial planes.

Flexural-slip folding produced a new foliation, S_3, which is characterized by crinkle folds whose axes form a lineation parallel to the b-direction (fold axis) of F_3 folds (Fig. 3d). S_3 crinkle folds are superimposed on, and occasionally better developed than, the earlier S_2 slip-cleavage. Often it is not possible to distinguish between S_2 and S_3 foliations in the outcrop because they are similar and usually parallel to each other. Locally, interference patterns have been observed with respect to the S_2 and S_3 cleavages. Unfortunately, this interference pattern was usually not adequately preserved or exposed to permit reliable field measurement of the fabric. This interference pattern may reflect local disharmonic folding of F_2 and F_3 folding or an even later episode of folding, as suggested earlier, with F_2 fold patterns.

Summarizing these data, it is concluded that F_2 and F_3 folding is coaxial. Inconclusive evidence suggests that F_1 folding may also be approximately coaxial with F_2 and F_3 folds. Some of the fabric data suggest that an episode of cross-folding or disharmonic folding has affected Chuacus rocks, at least locally. However, at the present time, it is not possible to determine whether this event represents an F_4 period of folding, or whether it is indicative of disharmonic folding or reorientation of strain patterns during the various phases of folding. It is also worth noting that Newcomb (1975) has recognized similar patterns of polydeformation in Chuacús rocks in the San Augustín Acasaquastlán and Río Hondo quadrangles, suggesting that this sequence of deformational events may be characteristic of much, if not all, of the Sierra de las Minas range.

AGE OF TECTONISM

Petrographic studies relating mineral paragenesis to deformational fabric, similar interpretation. Additional field mapping in greater detail in some of the more inaccessible regions of the study area along with more detailed structural fabric studies could do much to resolve this problem.

Farther to the west in the Central American Cordillera, McBirney (1963) and Kesler and others (1970) have also recognized polydeformation in Chuacus rocks. Although they did not chronologically define observed strain facies as in this investigation, their results could be interpreted as being consistent with those in this report. If this conclusion is valid then it is tempting to suggest that much of the Paleozoic Central American Cordillera is characterized by a series of refolded nappes that have been reoriented due to subsequent relative westward movement of the North American plate by processes described by Roper (1974) in his model of plastic plate tectonics.

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to those of Zwart (1960), Spry (1969), and Roper and Dunn (1973), suggest that only one main period of progressive regional metamorphism accompanied the three phases of folding. No unequivocal textural evidence indicates that any significant recrystallization occurred during F_1, F_2 or F_3 folding, suggesting that these fold systems represent different phases of one major orogenic event. These relationships together with co-axial multiple folding, suggest that the most logical time for this tectonism to have occurred, according to McBirney's 1969 dates, was during the middle Paleozoic. This interpretation assumes that the Precambrian date obtained by McBirney (1969) reflected detrital zircon inherited from an older rock.

TECTONIC INTERPRETATION

At the present time it is not possible to determine accurately the amount of crustal shortening associated with folding. However, in the western part of El Progreso quadrangle (Fig. 2), especially in the vicinity of Cerro Gordo, the S_1 foliation is almost horizontal for a distance of at least 5km (Fig. 6). This subhorizontal orientation of S_1 extends to the northern end of the quadrangle, which is an additional 3km. Although S_1 is locally refolded by F_2, there is nowhere along this length any indication that the hinge of the F_1 fold is being approached. The region south of Cerro Gordo is partially covered by a serpentinite thrust sheet. South of the thrust sheet are additional exposures of the Jones formation which are at approximately the same stratigraphic level as the rocks at Cerro Gordo. The horizontal distance of the Jones Formation south of the serpentinite body is about 3km. Thus, the minimum length of crustal shortening due to recumbent folding, excluding superimposed F_2 folds, in El Progreso quadrangle is at least 14km.

(Bailey, 1922; Hill, 1953; Billings, 1972; Goguel, 1972; Spencer, 1977) define a nappe as a mass brought forward to a notable extent, usually greater than one mile, by recumbent anticlinal folding or thrusting. According to this definition, the F_1 recumbent isocline can be described as a type of nappe. The expression "refolded nappe" is probably more appropriate because it has additional post - F_1 folds superimposed upon it. This structure has now been recognized along approximately 50 mi (90km) of the Sierra de las Minas range, suggesting that most, if not all, of the southern portion of this mountain range is characterized as a major east-west trending refolded nappe.

Roper (1976) described this nappe in greater detail with respect to lithologic zonations and suggested that only the upper half of the structure has been eroded to what would be equivalent to the transition zone of Wegman (1935) or the Abscherung zone of Haller (1956). Further to the east the higher grade metamorphic rocks described by Newcomb (1975) may be representative of those closer to the core of infrastructure of Wegman (1935) or Unterbau of Haller (1956).

No Chuacus rocks have been reported south of the Motagua fault zone. The S_1 foliation in these rocks has a tendency to dip more steeply to the south as the northern boundary of the fault zone is approached. This relationship may suggest that the hinge or root zone of the F_1 recumbent fold may occur near or within the Motagua fault zone, and has since been obliterated by faulting.

The location of the nappe hinge and root zone is controversial. One possible method of predicting their location relies on two assumptions. Firstly, is that F_1 and F_2 folds are part of the same strain pattern. Secondly, is that the interpretation that the present rocks represent the upper half of a refolded nappe is correct. If these assumptions are correct, then it can be noted from the information presented earlier that F_2 folds are predominantly overturned to the south which suggests that the hinge of the nappe lies in that direction. However, if it can be demonstrated that one or both of these assumptions is not valid, or that one of the stain facies is more disharmonic than observed in this study then it will be necessary to reassess this

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FIGURES

Figure 1 Map showing location of study area and its relationship to the regional geology of Guatemala.

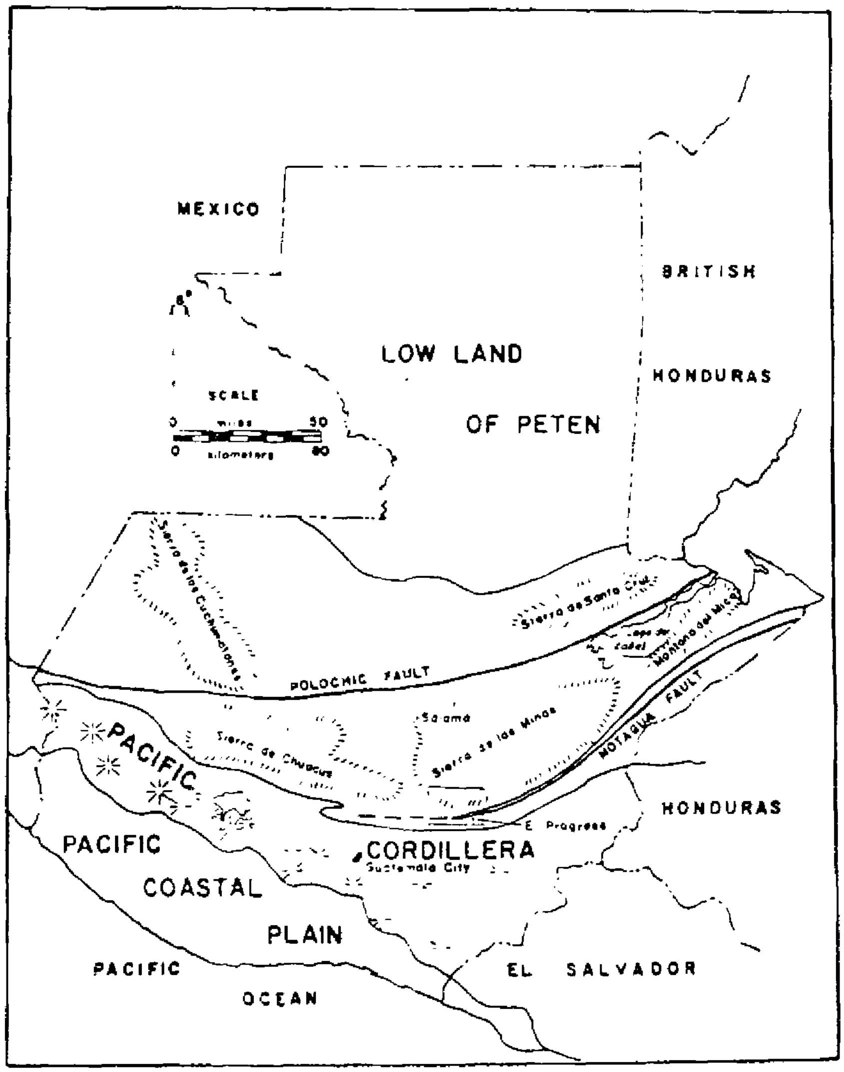
Figure 2 Geologic map of the northern portion of El Progreso quadrangle. The Río Motagua parallels the Motagua fault zone.

Figure 3 Lower hemisphere Schmidt π-diagrams illustrating tectonite fabric in the Chuacus Group. A) Contoured - diagram of 85 poles to S_1 foliation in Chuacús Group, 1, 3, 5, 7 percent. b) 27 fold axes lineations in Chuacús Group. C) 17 poles to fold axial planes in Chuacús Group. D) 16 slip-cleavage and crinkle fold lineations in Chuacús Group. In diagrams B-C solid ▲ represents F_1 fold, dot represents overturned to isoclinal F_2 folds, x represents F_2 open flexural slip folds.

Figure 4 Illustrates both F_1 and F_2 folds. South is to the right. Drawing below outlines the boundaries of the F_1 and F_2 folds in the photo.

Figure 5 Illustrates the co-axial relationship of F_2 overturned and F_3 flexural-slip folds. The radial or fan shaped distribution of F_3 axial planes with respect to F_2 axial planes is also illustrated in this photo. South is to the left. Exposure consists of mica schist and marble of the Jones Formation along the highway on the east side of Cerro Gordo.

Figure 6 Photograph illustrating S_1 foliation in Jones Formation which is nearly horizontal. Light colored lenticular rocks are sheared-out limbs and flattened rootless hinges of folds. Darker rocks are mica schist. Location of outcrop is along the highway on the eastside of Cerro Gordo.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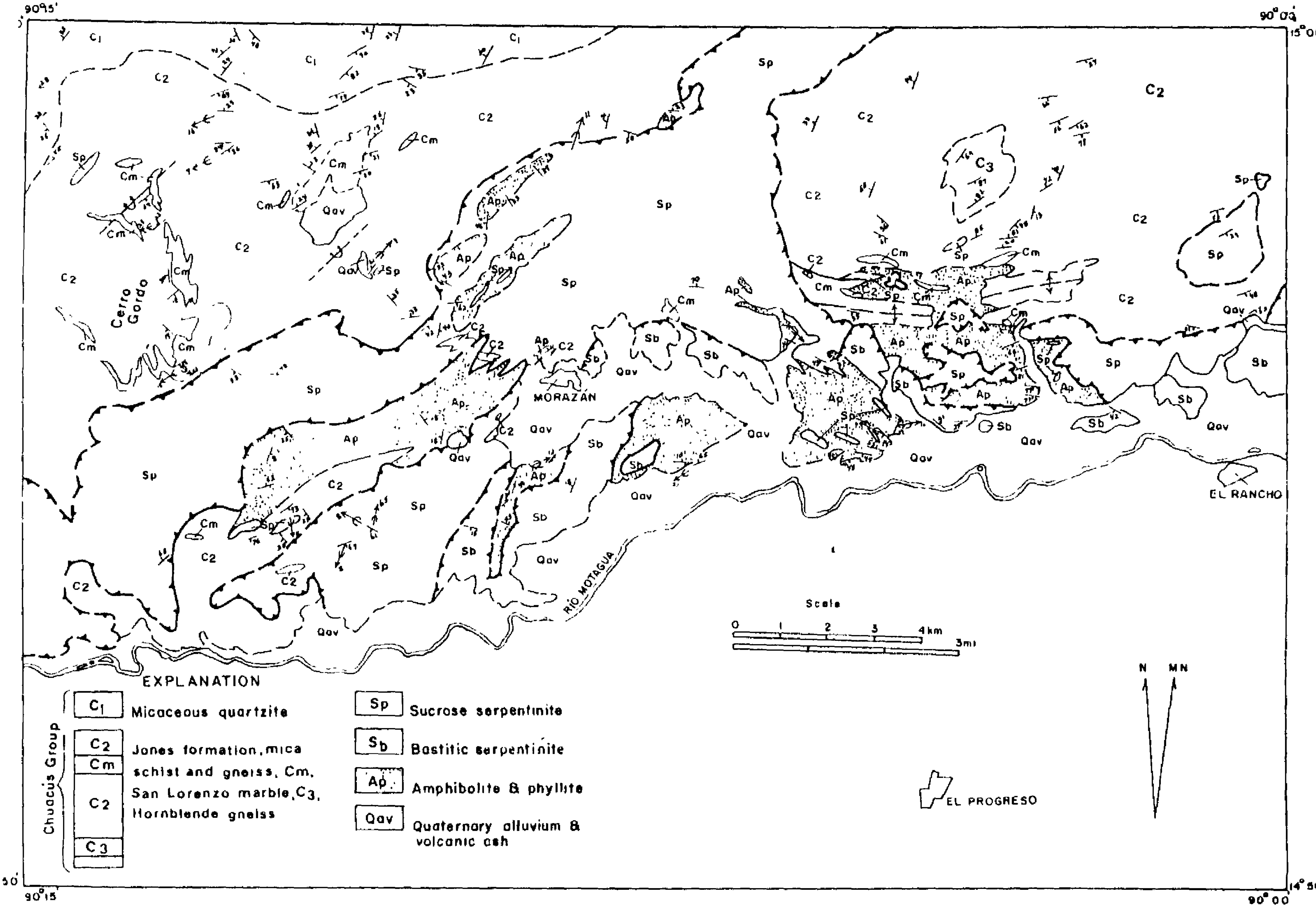
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Cerro Gordo
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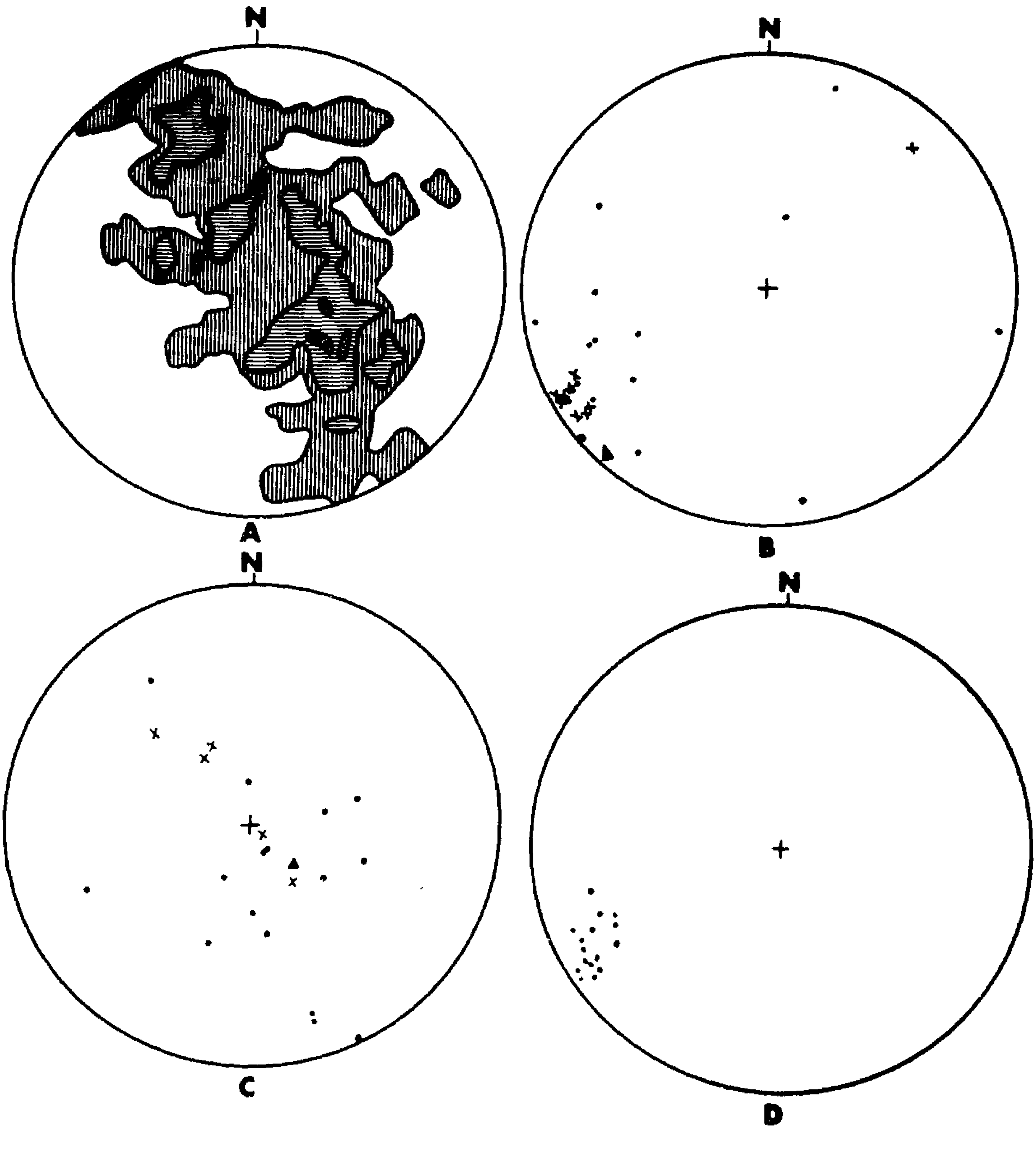
EXPLANATION
C1 Micaceous quartzite
Chuacus Group
C2 Cm C2 C3 Jones formation, mica schist and gneiss, Cm, San Lorenzo marble, C3, Hornblende gneiss
Sp Sucrose serpentinite
Sb Bastitic serpentinite
Ap Amphibolite & phyllite
Qav Quaternary alluvium & volcanic ash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