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GEOLOGY OF THE FRA CRISTOBAL RANGE

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INTRODUCTION

The Fra Cristobal Range is located in northeastern Sierra County, New Mexico, and forms a part of the discontinuous chain of north-trending mountains on the east side of the Rio Grande. The range is more accessible from the east through the Jornada del Muerto.

Most of the mountainous uplands comprising this range consist of high limestone ridges and peaks separated by deep valleys. Drainage seems to be controlled not only by the form of the uplift, but also by zones of structural weakness. At the southern extremity of the range, the upland zone changes rather abruptly into an area of low ridges and valleys capped by lava mesas and cones. It is here that the Cuchillo and Jornada pediment surfaces, which slope away from the range to the west and east, respectively, are believed to have been coextensive.

Although to date there is no detailed publication available on the entire range, numerous geologists have visited the area. Among the early workers were G. G. Shumard, W. T. Lee, C. R. Keyes, and N. H. Darton. The article by Harley (1934) is a compilation of these early reports. Recently Kelley and Silver (1952) have made important observations concerning the structure and lower Paleozoic stratigraphy of the Fra Cristobal Range. Bushnell (1953) made a valuable contribution to the understanding of the stratigraphy of the Cretaceous and Tertiary formations in the area immediately south of the range. Thompson (1955) recently completed a thesis on the southern part of the range concerning primarily the structural geology of the area. Eugene Cserna has just completed a doctoral dissertation of the geology of the Fra Cristobal Range at Columbia University under a research grant from the New Mexico Bureau of Mines. However, this dissertation was not available at this writing. The purpose of the following report is to present a summary of the current knowledge of the Fra Cristobal Range, and, to accomplish this, the author has drawn information freely from other sources.

STRATIGRAPHY

Precambrian exposures are generally confined to the western scarp of the range. The composition of these rocks is mainly granite with minor amounts of schist, hornblende diorite, and pegmatite. It seems likely that these rocks, or their derivatives, were the objective of the first mining claim in New Mexico filed on March 26, 1685, by one Pedro de Abalos, a private in the Spanish Army. The claim was in the northern part of the Fra Cristobal Range and was probably a lode or placer gold prospect.

The Cambrian Bliss formation ranges from 92 to 161 feet thick and is composed mainly of siltstone and sandstone with minor amounts of limestone and hematite, although the hematite is locally abundant. Its outcrop may be discerned from U. S. Highway 85 as a thin dark band immediately overlying reddish pink granite. The exposed formations of the Ordovician El Paso group are the Sierrite limestone consisting of 65 feet of limestone with banded chert, and 105 feet of Bat Cave limestone with nodular chert and dolomite with banded chert. (Kelley and Silver, 1952, Fig. 3).

The pre-Pennsylvanian Paleozoic formations pinch out northward in this region. (Kelley and Silver, 1952, Fig. 24). The Bliss pinch-out occurs to the north of the range, and southward the pinch-outs of progressively younger Ordovician formations occur beneath the Pennsylvanian rocks. Silurian, Devonian, and Mississippian strata pinch out south of the range.

In addition to the Precambrian rocks, the northern Fra Cristobal Range appears to consist largely of exposures of the Pennsylvanian Magdalena group. These strata are gently dipping except where bounding faults or isolated belts of folding have steeply disposed them. Marine limestone and shale are the dominant constituents of the Magdalena group. The uppermost limestone beds contain abundant crinoid stems. No intertonguing with the Abo has been noted.

Permian rocks are well exposed and are widely distributed in the southern part of the Fra Cristobal Range. Approximately 450 feet of the Abo formation disconformably overlies the Magdalena group, and is composed of irregularly bedded silt, clay, shale, and sand, with minor local beds of conglomerate. The bright red color of this formation makes it easily recognizable from a distance. Several small reptile tracks were found in the Abo which attest to the continental floodplain origin of the formation.

Immediately overlying the Abo formation, the

Yeso crops out mainly in slopes below the more resistant San Andres limestone ridges and peaks. Near its base, where some intertonguing with Abo-type lithology may occur, the Yeso is an even-bedded brown calcareous sandstone and siltstone with intercalated thin limestone beds and gray claystone. In the middle of the section the sandstone beds give way to thin-bedded limestone and gypsum units. Towards the top medium-to thin-bedded limestone beds occur, but the uppermost Yeso unit is brown sandstone. Judgment as to what is a representative thickness is made difficult by the plastic flowage, folding, and faulting which have taken place, but the Yeso is estimated to be 595 feet thick in this area. Some of the marine limestone beds locally contain specimens of the brachiopod *Dictyoclostus* sp., but on the whole the Yeso is sparsely fossiliferous.

From the transition strata of the Yeso, the Permian section grades upward into the marine carbonates of the San Andres formation. Bold, sheer escarpments on the sides of rugged-topped ridges and peaks are characteristic of the exposures of the San Andres at the tapering end of the southern part of the range. This formation is composed of thin-to thick-bedded, fine-grained, gray limestone that weathers gray, buff or tan. A few thin sand beds and dolomitic, sandy, or cherty limestone beds are scattered throughout the 613-foot San Andres section. Although they are poorly preserved, numerous specimens of *Dictyoclostus* sp. occur with other brachiopods, gastropods, cephalopods, and foraminifers in the fossiliferous intervals.

Triassic, Jurassic, and Lower Cretaceous strata are absent in this area, and Upper Cretaceous rocks rest upon the eroded top of the San Andres formation. The Dakota formation is a thin basal conglomerate and sandstone. The remainder of the Cretaceous and Tertiary section lies in the lowlands adjoining the Fra Cristobal Range.

A thin, black Mancos shale interval is overlain by a thick section of the Mesaverde and McRae formations. The 2,000 foot main body of the Mesaverde formation is capped by about 100 feet of the Ash Canyon conglomeratic member. The Jose Creek member of the McRae formation consists of approximately 400 feet of olive-drab shale, dark brown to greenish andesitic sandstone, and bedded chert. Above it is the Hall Lake member of the McRae, a 2,200 foot section of purple and maroon shale with minor beds of sandstone. Tertiary rocks in the area are the Santa Fe formation and some olivine basalt dikes and lava flows. Quaternary alluvium, pediment gravel, and basalt plugs and extrusions are widespread along the slopes of the Fra Cristobal Range.

STRUCTURE

Broadly speaking, the Fra Cristobal Range is a north-trending horst with the Jornada del Muerto depression to the east and the Rio Grande depression to the west. It is bounded on the north by the San Pascual platform and on the south by the Cutter sag, separating it from the Caballo uplift. The principal structures resulting from the tectonic development of the range may be arbitrarily placed in three age groups: Laramide, middle Tertiary, and late Tertiary.

During the Laramide orogeny compressive forces formed sets of closed folds which trend north to northwest. Locally these folds are overturned to the east or northeast. The overturned portions of the folds occur in isolated belts separated by wide areas of relatively undeformed strata, but in places these overturns break into thrust faults dipping to the west. In addition, some long thrusts, also dipping west, in the northwestern part of the range attest to the intensity of the orogeny.

After Laramide time, probably in middle Tertiary, the Fra Cristobal area was subjected to a period of uplift producing a few open folds and several normal faults. The grain of the structures developed during this uplift is mainly north-south, but inherent weaknesses resulting from the Laramide revolution appear to have predetermined the northwest trend of some of the faults. The Hot Springs fault of Kelley and Silver (1952, p. 159) has been traced northward where it forms the western scarp of the Fra Cristobal Range. On the east side, the Fra Cristobal fault intersects the Hot Springs fault at the north end, but dies out into an anticline at the south end of the range. The formation of both of these major faults resulted in most of the structural relief of the Fra Cristobal uplift above the adjoining depressions.

A prominent set of northeast-trending faults offset the middle Tertiary faults, but do not disrupt the Quaternary lava flows. For this reason they are dated as late Tertiary. South of the range proper, the late Tertiary faults are practically parallel; however, within the range they branch and turn to assume a more northerly trend. All of these faults are of the high-angle normal type, but some of them exhibit a component of strike-slip movement as indicated by drag and offset. Right-lateral slip is more prevalent than left-lateral, yet both types are present. Some of the drag folds appear to contradict the movement indicated by offset; nevertheless they may be explained in several ways (Thompson, 1955, p. 62-63). Furthermore the Hot Springs faults, which was prob-

ably reactivated during late Tertiary, shows left-lateral drag in the Caballo Mountains and right-lateral drag locally near the Fra Cristobal Range. Again these seemingly incompatible relationships may be reconciled (Thompson, 1955, p. 63-66), but definite conclusions depend upon a more precise knowledge of the physical conditions under which drag is formed.

It appears doubtful that deformation in this area ceased at the end of Tertiary time. Indeed, diastrophism may have continued to the present day as evidenced by recent fault scarps and recorded earthquakes.

SUMMARY

After Precambrian time the dominantly carbonate Paleozoic section in the Fra Cristobal area was subjected to several broad epeirogenic uplifts. In contrast, the clastic composition of the Mesozoic and Cenozoic rocks reflect a more intense diastrophic history. Overturned folds and thrust faults were formed during the Laramide orogeny. Uplift in middle Tertiary produced several broad folds and high-angle faults. Late Tertiary normal faulting was accompanied by lateral shearing to produce a strike-slip component of movement. Development of Quaternary pediment was followed by the eruption of basaltic cones.

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