THE EMPIRE MOUNTAINS, PIMA COUNTY, ARIZONA

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INTRODUCTION

The Empire Mountains occupy about 30 square miles in southeastern Pima County (fig. 48), and consist of two parallel ridges trending north-northeast. They are connected with the Santa Rita Mountains to the west by low rolling foothills and are separated from the Whetstone Mountains to the east by the broad floor of Cienaga Wash valley.

The Empire Mountains (fig. 23) are made up of marine limestone, shale, and quartzite of Cambrian, Devonian, Mississippian, Pennsylvanian, and Permian age, aggregating approximately 5,700 feet in thickness, and a series of Cretaceous (?) continental clastic deposits possibly 18,000 feet in thickness. The sedimentary rocks are intruded by stock-like bodies of quartz monzonite and granodiorite and by dikes ranging in composition from rhyolite to basalt.

The range has two structural parts - an underlying block of Cretaceous (?) rocks, and an overthrust block of Paleozoic and Cretaceous (?) rocks which is divided into four segments by northwesterly striking tear-faults. The thrust fault is exposed along the western edge of the mountains and dips to the east at a low angle. Within the overthrust block there are at least three separate imbricate thrust sheets. Domes, anticlines, and overturned folds have been formed in the Paleozoic rocks.

STRATIGRAPHIC UNITS

Bolsa (?) Quartzite

A small area of dense, glassy quartzite is exposed between the Pantano Hill stock and the Abrigo formation in the northern part of the range. Although the exposure is only a few feet in thickness, it is considered to be Bolsa quartzite because it is similar in appearance to typical Bolsa quartzite and lies conformably below the Abrigo formation.

Upper Cambrian Abrigo Formation

The Abrigo formation consists of soft, light gray to blue layers of limestone, alternating with thin beds of green shale, light gray sandstone, and brown to black chert. Beds are generally from one-half to three inches thick, lenticular, and their exposures have a characteristic mottled appearance. In some places the top of the formation is marked by a 5 to 6 foot bed of pure white quartzite. Maximum exposed thickness is 750 feet.

Upper Devonian Martin Limestone

The Martin limestone is composed of finely crystalline limestone, gray and moderately thick-bedded at the base, and thinner-bedded and less resistant to erosion toward the top. The top of the formation in the northern part of the range is marked by a horizon composed largely of *Cladopora prolifica*. In the southern part of the range a zone of soft, shaly beds has been interpreted as the top of the Devonian section. Metamorphism has transformed large masses of the lower limestones into

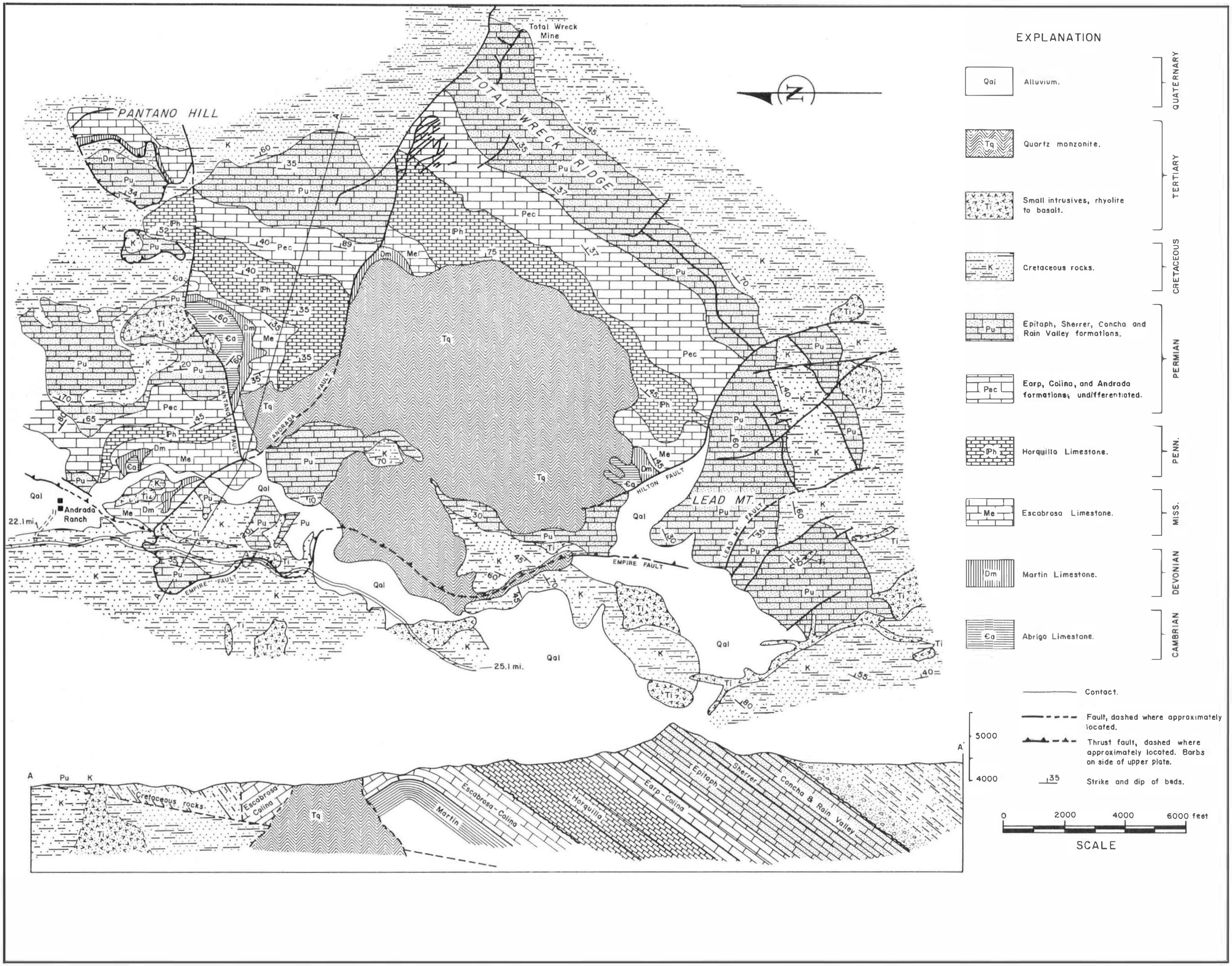

FIGURE 23. Generalized geologic map and cross section of the Empire Mountains, Cochise County, Arizona.

sparkling, sugary to coarsely crystalline marble. The thickness ranges from about 300 feet in the southern part to about 100 feet in the northern part of the range.

Lower Mississippian Escabrosa Limestone

The Escabrosa limestone is exposed almost continuously throughout the length of the range, but is unusual in that it is not a cliff-former in this area. The Escabrosa consists of light gray to blue, fine-grained limestone beds one to two feet thick. Metamorphism has changed much of the formation to white, coarsely-crystalline marble; which closely resembles the marbleized limestone in the Martin, and makes difficult the separation of Mississippian and Devonian limestones where the Cladopora prolifica horizon is not present. The Escabrosa ranges in thickness from 200 to 600 feet, thickening from south to north.

Pennsylvanian Horquilla Formation

A disconformity, marked in places by a thin bed of conglomerate separates the Horquilla from the underlying Escabrosa. The Horquilla generally consists of massive, blue-gray limestone alternating with soft calcareous shale. Individual beds are from 10 to 100 feet thick. Limestone beds are thicker than shale beds and stand out on weathered slopes, giving a coarsely banded appearance to the formation as a whole. In the northeastern part of the Empires, however, the lower part of the Horquilla formation consists of alternating limestone and quartzite beds, and shale predominates in the upper part. The limestone beds are one to three feet thick, fine grained, dark blue, and contain irregular chert inclusions. The quartzite beds are light gray or white on fresh surfaces and weather to buff.

Metamorphism has obliterated the bedding and blue-gray color of the limestone beds and changed the shale to hard, resistant, hornfels-like masses. The Horquilla is nearly 1,200 feet thick in the central part of the range but thins northward to approximately 500 feet.

Pennsylvanian and Permian Andrada Formation

The Earp and Colina formations defined by Gilluly, Cooper, and Williams (1954), cannot be recognized in the Empire Mountains, and the term Andrada formation has been used by Wilson, E. D. (1951), Bryant (1955), and others for the undifferentiated equivalent beds. In the Empire Mountains the Andrada formation consists mainly of soft shale and marl, with some dense, dark blue-gray limestone from 10 to 200 feet thick, and, in the upper part, three beds of gypsum from 5 to 50 feet thick.

Many beds of the Andrada formation exhibit a complete change in lithologic character within a few hundred feet along strike. The formation as a whole is soft, and erosion has carved the main north-south wash from these unresistant beds.

Locally, metamorphism along intrusive contacts has converted part of the Andrada formation to a fissile, light gray, sericite schist which resembles the Precambrian Pinal schist. Where the formation lies at greater distances from intrusive bodies, the limestone has been marbleized, and the shale has been indurated or silicified to hornfels-like masses which closely resemble the metamorphosed Horquilla.

The Andrada formation ranges in thickness from 300 to 1,500 feet. It is thickest in the central part of the range and thins to the north.

Permian Epitaph, Scherrer, Concha, and "Rainvalley" Formations

The undifferentiated Epitaph, Scherrer, Concha, and "Rainvalley" formations, from 1,250 to 2,250 feet in thickness, are the most prominent rocks in the Empire Mountains. They form the crests of the highest ridges and their western slopes are usually sheer cliffs that are visible for miles. Although these formations, defined by Gilluly, Cooper, and Williams (1954), can be readily recognized, they have been mapped as a unit.

The Epitaph consists of a series of thick, massive, fetid limestone beds 90 to 300 feet thick and forms the prominent westward facing cliffs along the higher parts of the range. The Scherrer formation is made up of two gray, vitreous, orthoquartzite members separated by a massive, blue, dolomitic limestone which usually contains irregular masses of silicious material. The lower quartzite member ranges in thickness from 90 to nearly 800 feet; the middle dolomitic limestone member is from 30 to 150 feet thick; and the upper quartzite member is from 30 to 250 feet thick. The thicknesses are greater in the southern part of the range, but the great change over relatively short distances is believed to be due to unrecognized low angle thrust faulting. The Concha and "Rainvalley" formations make up an unbroken series of limestone beds above the Scherrer, and form the eastern slopes of the highest ridges. The Concha maintains a thickness of about 500 to 600 feet and consists of dark gray to blue limestone beds which are thick, massive, and fetid, and contain abundant chert nodules in many places. The "Rainvalley" consists of light gray dolomitic limestone which is thinner bedded than the Concha, and a few thin beds of brown to buff quartzite.

Cretaceous (?) Beds

Cretaceous (?) rocks are divided into two major units, those on the east and those on the west sides of the thrust fault. The lack of fossils and marker beds prevents correlation across the thrust. The strata on the west side of the fault are further subdivided into a northern and southern series, separated by a high-angle fault. These strata are considered to be of probable Cretaceous age, because of their lithologic similarity to rocks in the Santa Rita Mountains (Schrader, 1915; Stoyanow, 1949).

On the east side of the Empire Mountains a series of conglomerate, shale, sandstone, and limestone beds lies unconformably upon a deeply eroded surface cut on Paleozoic rocks. The differences in dip between the Cretaceous (?) and Paleozoic strata are slight, but the differences in trend are clearly visible on aerial photographs. The lower part of the series consists predominantly of sandy maroon shale containing one or more beds of conglomerate composed of pebbles, cobbles, and boulders of Paleozoic limestone. In places conglomerate rests directly upon the eroded surface of the "Rainvalley" or older formations, and elsewhere the lowest bed of conglomerate lies upon 400 feet of maroon Cretaceous (?) shale. The maroon shale series grades upward into coarse gray arkosic sandstone and predominantly gray shale with occasional thin beds of limestone which are either extremely shaly or black and fetid. These Cretaceous (?) beds dip southeast from 20 to 30 degrees and are about 8,700 feet thick. The alluvium of Cienega Wash valley covers them to the east.

On the western side of the range, below the thrust plane of the Empire fault, the Cretaceous (?) beds consist of a northern and southern series separated by a high angle fault. The northern series is made up of coarse gray to brown arkosic sandstone, greenish-gray shale, and occasional lenticular limestone beds which are extremely thin-bedded and either light gray or jet black and fetid. Lithologically these beds are similar to those which lie above the maroon shales on the eastern flank of the mountains and may be either their equivalent, or represent the beds now concealed beneath the alluvium of Cienega Wash valley.

The southern series of Cretaceous (?) beds west of the thrust is made up of thick boulder conglomerate alternating with felsic lava flows and tuffs. Their relationship to the other Cretaceous (?) strata is not known, but they are presumably younger than the arkosic sandstone and shale, because they contain numerous fragments of arkosic rocks which appear to be identical with those exposed to the north. This series may be in part as young as Tertiary in age.

The structural and stratigraphic relationships of the Cretaceous rocks between the Empire and Santa Rita Mountains are complex, and it has not yet been possible to establish a continuous sequence between these two ranges. Near the crest of the Santa Ritas, the maroon shale and limestone conglomerate series lies unconformably on the Paleozoic rocks and dips eastward, and an arkosic sandstone and shale series is present. The total thickness of Cretaceous rocks between the Santa Rita Mountains and the western margin of the Paleozoic section in the Empire thrust block may be about 18,000 feet, but the possibility of duplication by folding or faulting cannot be disregarded.

INTRUSIVE ROCKS

The central part of the Empire Mountains is occupied by the Sycamore quartz-monzonite which extends for about two miles along the trend of the range as a roughly elliptical body less than one mile wide. On the western side of the mountains it is in contact with the Cretaceous (?) beds of the basement block; along the remainder of its border it rests against the Paleozoic rocks of the overthrust block. The quartz-monzonite is light gray and medium to coarse grained.

Small bodies of granodiorite, rhyolite porphyry, rhyolite, and diorite porphyry are exposed near the Sycamore stock, and small dikes of aplite, syenite, trachyte, rhyolite, diorite, andesite, and basalt occur throughout the Empire Mountains.

STRUCTURE

The Empire Mountains are divided into two structural parts, a basement block of Cretaceous (?) rocks, in part folded into a series of broad anticlines and synclines with east-west axes, and in part dipping steeply to the east; and an overthrust block of Paleozoic and Cretaceous (?) strata which dip eastward at about 45 degrees. East-west and north-south faults have added to the structural complexity of the range.

Basement Block

The basement block is exposed in and forms the foothills between the Empire and Santa Rita ranges. It is divided by a high-angle, northwest-southeast fault into two distinct parts. The northern part consists of Cretaceous (?) arkosic sandstones and shales, and the southern part consists of Cretaceous (?) boulder-conglomerate and volcanic flows and clastic rocks. The rocks of the northern series have been folded into broad anticlines and synclines with east-west axes striking nearly at right angles to strata above the thrust. The amplitude of the folds is greater than 2,000 feet and the dip of the beds on the flanks range from 40 to 60 degrees. The conglomerate and volcanic strata of the southern series dip from 65 to 80 degrees to the east. Along a large part of its length the fault which separates the two series is occupied by a dike of rhyolite porphyry.

Overthrust Block

The dominant structural feature of the Empire Mountains is a low-angle fault which crops out along the western edge of the mountains and appears to dip gently toward the southeast. Although the outcrop of the fault is covered largely by the alluvium, it is exposed southwest of the Andrada Ranch where Permian limestone rests on the folded Cretaceous (?) rocks of the northern series. To the south, where the fault is not exposed, Cretaceous (?) rocks are almost everywhere exposed on the west bank of Davidson Canyon, and, except in the vicinity of the Sycamore stock, Paleozoic rocks make up the east bank.

In the northernmost part of the range, imbricate thrust structure is strikingly developed. At the southwestern base of Pantano Hill, limestone beds rest on Cretaceous (?) maroon shale and limestone conglomerate. Near the crest of Pantano Hill, a basal Cretaceous (?) limestone conglomerate, 30 to 50 feet thick, rests on the eroded surface of the Scherrer formation. Above the conglomerate is a sliver of Martin limestone, replete with Atrypa reticularis, and Escabrosa limestone.

The main overthrust block of the Empire Mountains is broken by east-west faults which divide it into four segments. The large horizontal component of displacement on some of these faults (about 8,000 feet on the Andrada fault and 6,000 feet on the Pantano fault) and the fact that they cannot be traced into the Cretaceous rocks of the basement block to the west, strongly suggests tear-faults which formed during the period of overthrusting. Structure within the individual segments also suggests that the displacement along these faults is the result of horizontal rather than vertical movement. In the northern segment, the Paleozoic formations are domed, and imbricate structure is present; in the north central segment, the Paleozoic rocks have been folded into a symmetrical anticline whose roughly north-south axis plunges steeply to the south; in the south central segment, there is an asymmetrical anticline with steeper dips to the west than to the east; and the southern segment apparently has been rotated on the thrust plane so that the formations exposed just south of the Hilton fault strike east instead of north.

The direction of the thrust appears to have been from the southeast. The Cretaceous (?) rocks below the imbricate thrust plates wedge out in this direction. The asymmetrical anticline and syncline which involves the Abrigo and Martin formations adjacent to the Hilton fault dips 45 degrees southeast. South of the Andrada Ranch a fold in the same formations is sharply overturned to the north, and the Martin limestone has been moved northward along a low-angle fault over the crushed shaly beds of the Abrigo formation.

Normal Faults

North-south normal faults in the Empire Mountains are inferred from displacements of formational contacts, but their outcrops are concealed by alluvium in most places. The amount of vertical displacement on these faults appears to have been moderate, amounting to only a few hundred feet at a maximum.

Interpretation of Structure

Large-scale overthrusting in southeastern Arizona has been described in the Santa Rita and Empire Mountains by Schrader (1915) and Wilson, R. A. (1934), in the Tucson Mountains by Brown (1939), and in central Cochise County by Gilluly (1956). Thrust faults of considerable magnitude are also known to be present in the Rincon, Sierrita, and Huachuca Mountains. In the Empire Mountains, the intensity of thrusting and accompanying folding and shearing contrast with the comparatively small-scale normal faulting exhibited along their flanks. Although the Empire Mountains outwardly exhibit the typical form of Basin-and-Range tilted-blocks, the displacements along the normal faults appear to be too small to account for the structural relationships of the Empire Mountains to the adjoining Santa Rita and Whetstone ranges. The author concludes that the structural development of the Empire Mountains was controlled by regional compression.