A GRAVITY STUDY OF THE SAN LUIS BASIN, COLORADO

by

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A GRAVITY AND SUBSURFACE STUDY OF THE
SAN LUIS BASIN, COLORADO

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ABSTRACT

The Rio Grande rift is a well-defined tectonic feature which dominates the north-south structural elements of central New Mexico and extends northward into south-central Colorado. The San Luis Basin constitutes the major structural element of this northward extension. A complete Bouguer gravity anomaly map of the San Luis Basin, based on about 5500 gravity stations, shows the basin to consist of two north-northwest trending grabens separated by a central and parallel horst. These features are bounded by faults or fault zones several kilometers wide. Thicknesses of Cenozoic sediments occupying the basin determined from gravity measurement and estimated or measured average rock densities, are typically about 1 km and reach a maximum of 2.9 km (9500 ft) immediately southwest of Crestone, Colorado. This maximum is substantially less than estimates from previous surveys and suggests that the San Luis Basin is not atypical, but instead typical in depth for basins associated with the Rio Grande rift. A broad gravity high can be distinguished from that caused by the intragraben horst and may indicate the presence of an upper crustal intrusive mass beneath the central and western portions of the San Luis Basin. This inferred intrusion occurs in an area of high measured heat flow and may be causally related. Finally, a positive correlation seems to exist between the eastern boundary fault(s) of the central horst within the San Luis Basin and the Pecos-Picuris fault as mapped by Sutherland (1963, 1972) and Mallory

(1960, 1972). This correlation suggests the presence of a zone of crustal weakness in this portion of the North American plate which may have influenced the development of the Rio Grande rift and the San Luis Basin.

TABLE OF CONTENTS

TABLE OF CONTENTS

INTRODUCTION

Bryan (1938), who coined the term "Rio Grande depression" to describe the structural element through which the Rio Grande flowed, included the San Luis Basin as a part of this elongate feature. Forty years later, the Rio Grande rift (Fig. 1) is recognized as the structural feature which has dominated the late Cenozoic tectonics of south-central Colorado and central New Mexico. It extends southward from Leadville, Colorado, at least as far as El Paso, Texas (Chapin, 1971).

The San Luis Basin constitutes the major structural element of the Rio Grande rift in Colorado. Although its surficial physiographic boundaries are well defined, its subsurface configuration is incompletely known. A lack of deep oil and gas exploration has hampered geological studies of the subsurface structure, while only three publically available geophysical studies have been completed in the area. A gravity study conducted by Gaca and Karig (1965) produced earth models for profiles across the valley at various points, but their efforts were hampered by the lack of topographic mapping in the area at scales greater than 1:250,000. A seismic reflection study by Stoughton (1977) provided seismic reflection profiles in the extreme northern and east-central portions of the basin and a resistivity survey by Arestad (1977) has outlined some potential geothermal energy sites in the same areas. However, these two surveys are limited in their areal extent and have

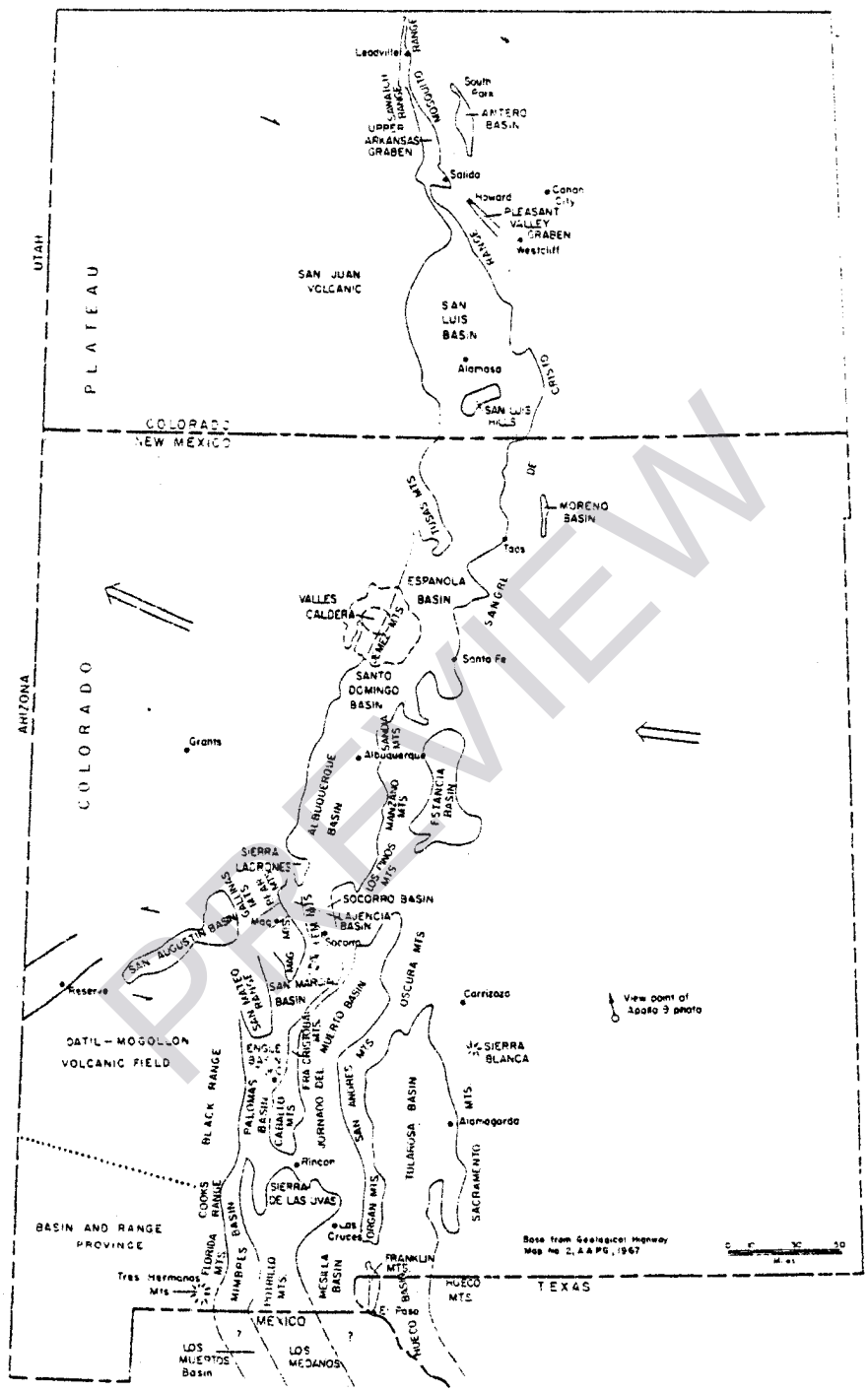

Figure 1. Generalized map of the Rio Grande rift (from Chapin, 1971)

not dealt with the remainder of the basin. An aeromagnetic map of Colorado (Zietz and Kirby, Jr., 1972) has been produced and shows the general structural grain of the basement rocks in the study area, but due to wide flight-line spacing does not lend itself to a detailed structural and subsurface analysis of the basin. Thus, a comprehensive understanding of the subsurface structure in the San Luis Basin and how it relates to the remainder of the Rio Grande rift is not available.

The purpose of this study is to present the results of a detailed gravity study conducted in the San Luis Basin and surrounding regions. By examining the Bouguer anomaly map and earth models produced utilizing these data, the subsurface structure of the basin and its relationship to adjacent areas has been analyzed. It is hoped that these results will further our understanding of this portion of the Rio Grande rift.

LOCATION AND PREVIOUS WORK

The San Luis Basin is an elongate intermontane valley located in south-central Colorado and extreme northern New Mexico. Stretching approximately 240 kilometers (km) in a north-south direction, it is bordered on the west by the San Juan and Tusas Mountains and on the east by the Sangre de Cristo Mountains. Extending southward from Poncha Pass, the valley is only 10-12 km wide, but widens to approximately 70 km near Alamosa (Fig. 2). The valley floor, although appearing relatively flat, is built from the coalescence of alluvial fans sloping gently outwards from the mountain flanks towards the center of the valley. Fifteen kilometers south of Alamosa, this sloping terrain is broken by the San Luis Hills, a series of flat-topped, low-lying volcanic hills extending along a north-south trend to the Colorado-New Mexico border. Geographically the valley has been arbitrarily defined as terminating 15 miles south of the state line (Siebenthal, 1910). Upson (1939) however has noted that the valley is not a geological entity unto itself and instead merges southward into the Taos Plateau, an idea which has wide acceptance. Kelley (1956), meanwhile, has extended the San Luis Valley to include the Taos Plateau and gives its southern termination as the Embudo constriction near Santa Fe.

Initial reports on the geology of the San Luis Valley and the surrounding mountains were made by Hayden (1869) and Endlich (1877). A more detailed account of its geology and

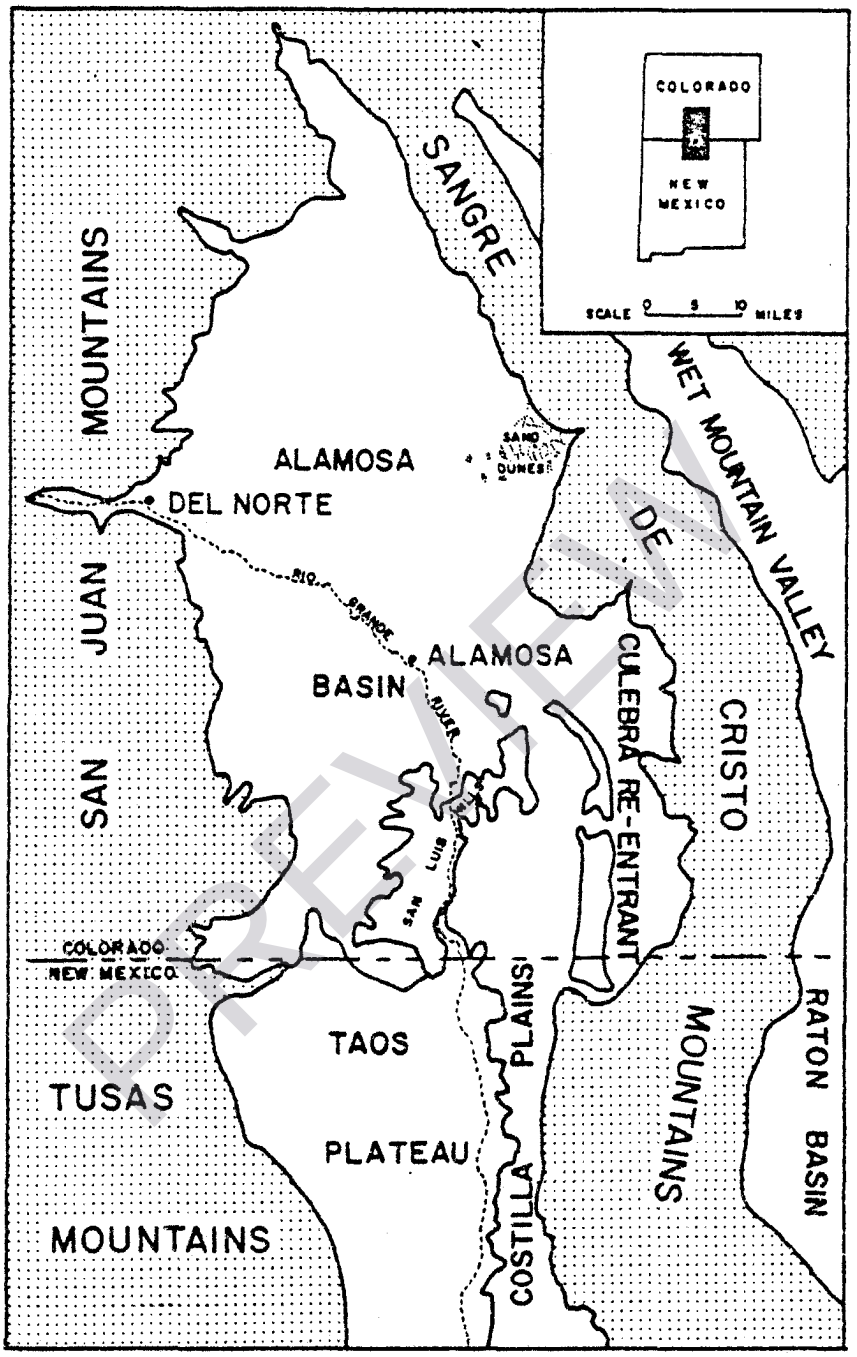

Figure 2. Physiographic subdivisions of the San Luis Valley, Colorado-New Mexico (modified from Upson, 1939)

geologic history was made by Siebenthal (1910). Upson (1939) defined five physiographic provinces in the valley (Fig. 2) and described their topographic and surficial geologic features. The Cenozoic deposits of the valley were described indirectly by Bryan (1938) in his description of the Santa Fe Formation of the Rio Grande rift area. Powell (1958) described these formations in greater detail and gave descriptions from logs of wells drilled in the valley. Baltz (1965) also described the Cenozoic faulting and sedimentation in the northern portion of the San Luis Valley. Several studies of the tectonic history of the valley and the northern Rio Grande rift in general have been completed (Bridwell, 1976; Kelley, 1952, 1956; Chapin, 1971; Chapin and Seager, 1975; Knepper and Maars, 1971; Knepper, 1975; and others).

The San Luis Hills have been discussed briefly by various authors, including Atwood and Mather (1932), Upson (1939), and Larsen and Cross (1956), while a more complete analysis of the area has been presented by Burroughs (1971).

Numerous field studies have been completed concerning the geology of the Sangre de Cristo Mountains (Burbank and Goddard, 1937; Gableman, 1951; Litsey, 1958; DeVoto et al., 1971; and others). In addition, a number of unpublished theses by students of the Colorado School of Mines have dealt with the perplexing geology of the northern portion of the range.

A host of studies have been completed concerning the geology and geochemistry of the San Juan Mountains and the volcanic series exposed therein. These include Atwood and Mather's (1932) discussion of the Quaternary physiography and geology, and Larsen and Cross' (1956) study of the complex pre-Quaternary geology and petrology, especially that of the Cenozoic volcanic series. Lipman and others (1970, 1978), through the use of K-Ar dating and Pb and Sr isotope studies, respectively, have studied the volcanic history of the region and have postulated a petrologic evolution of this volcanic suite. The results of a gravity survey performed in the region by Plouff and Pakiser (1971) have indicated the possible presence of a near-surface batholith beneath the San Juan volcanic pile, a theory which has gained much support in recent years.

GEOLOGIC HISTORY AND TECTONIC SETTING

Precambrian

The Precambrian history of the San Luis Valley, although incompletely known, is apparently complex. The entire west flank of the Sangre de Cristo Range in Colorado and northern New Mexico, as well as portions of the Wet Mountains and the Tusas Mountains are composed of Precambrian rocks. Examination of these exposures suggests the following rather simplified geologic history. Numerous sedimentary sequences of probable early Precambrian age were tectonically deformed and intensely metamorphosed during middle Precambrian time into folded sequences of gneissic and schistose metasediments. These, in turn, were intruded by middle to late Precambrian (Hedge, 1972) plutons of silicic and intermediate compositions which were probably orogenically emplaced. Although evidence of uplift accompanying this supposed orogenic activity is sketchy, depths of erosion in the larger plutonic bodies do indicate extensive erosion (Boyer, 1962) and therefore uplift. Also, nonconformities are found to occur between the Precambrian crystalline basement and the overlying Paleozoic rocks (Litsey, 1958). Sutherland (1972) has documented approximately 23 km of Precambrian-age right lateral strike slip movement on the Pecos-Picuris fault in northern New Mexico. In fact, numerous faults which border the present Precambrian exposures have been suggested to have been tectonically active during Precambrian time (Tweto, 1975).

Early and Middle Paleozoic

At the close of the Precambrian era the study area was a part of a broad, relatively stable, positive element known as the Transcontinental Arch which, in Colorado, was composed of two highlands, Siouxia and Sierra Grande, bisected by a shallow trough, the Colorado Sag (Fig. 3). Pre-Pennsylvanian sedimentation was controlled by this tectonic feature. Relatively uniform accumulations of clear-water carbonate rocks and clean quartzose sandstones separated by disconformities indicate that epeirogenic events caused transgression and regression of the eastern and western epeiric seas across the area and accompanying periods of erosion. The absence of Silurian rocks in the area is probably due to one such period of widespread erosion during late Silurian to middle Devonian time (Haun and Kent, 1965) rather than to nondeposition (Fig. 4). The best preservation of pre-Pennsylvanian strata in the study area is in the Kerber Creek region of the northern San Juan Mountains where thicknesses of the section average between 200 and 350 meters (Knepper and Maars, 1971), and in the northern Sangre de Cristo Range where varying thicknesses of the same order are observed (Litsey, 1958). These two areas were located in a shallow trough, the Colorado Sag (Fig. 3), which probably received thicker accumulations of these pre-Pennsylvanian sediments. Broad regional uplift and widespread erosion occurred throughout the study area at the end of late Mississippian time and continued into the early Pennsylvanian.

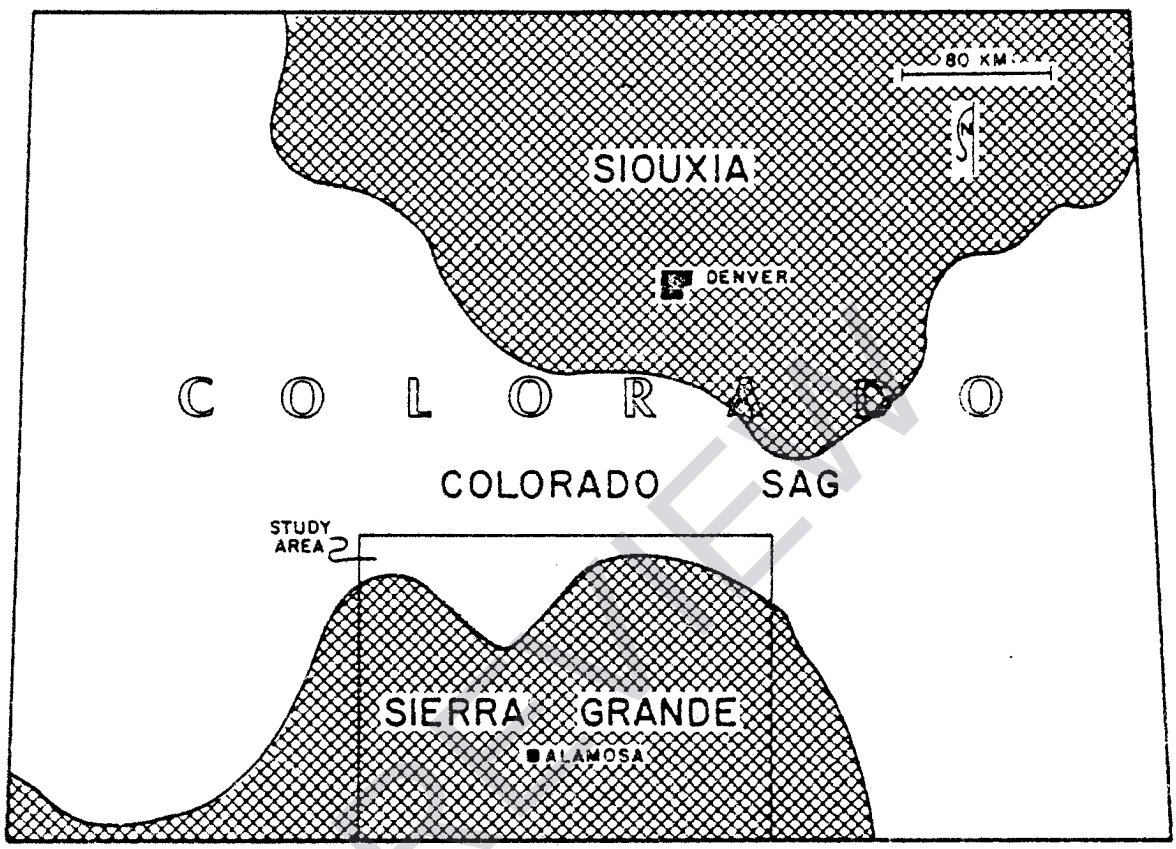

Figure 3. General outline of early Paleozoic highland areas in Colorado (modified from Berg, 1960)

AGE			UNIT	THICKNESS (IN FEET)
CENOZOIC	Quaternary	RECENT & PLEISTOCENE	Alamosa Fm.	0-5000?
			Servilleta Basalt	0-1000?
	TERTIARY	PLIOCENE and/or MIOCENE	Santa Fe Fm.	0-5000?
			Hinsdale Basalt	0-1000?
			Los Pinos Gravel	0-1300?
			Devils Hole Fm.	25-1300
		OLIGOCENE	Volcanics of the San Juan Mts.	
			Farisita Cong.	0-1200
		EOCENE	Huerfano Fm.	0-2000
			Cuchara Fm.	0-5000
		PALEOCENE	Poison Canyon Fm.	0-2500
			Raton Fm.	0-1700
MESOZOIC	CRETACEOUS		Vermejo Fm.	200-550
			Trinidad Ss.	0-300
			Pierre Sh.	0-2300
			Niobrara Fm.	500-630
			Carlisle Sh.	165-235
			Greenhorn Lm.	30-80
			Graneros Sh.	185-380
			Dakota Ss.	100-150
			Purgatoire Fm.	115-195
	JURASSIC		Morrison Fm.	200-400
			Ralston Creek Fm.	50-100
			Entrada Ss.	0-100
	TRIASSIC		Dockum Group	0-800
PALEOZOIC	PERMIAN		Sangre de Cristo Fm.	6300-9500
	PENNSYLVANIAN		Whiskey Creek Pass Fm.	150-300
			Minturn Fm.	2000-5500
			Sharpsdale Fm.	900-1200
			Kerber Fm.	100-300
	MISSISSIPPIAN		Leadville Lm.	210-330
	DEVONIAN		Chaffee Fm.	95-185
	ORDOVICIAN		Fremont Fm.	230-300
			Harding Ss.	60-116
			Manitou Fm.	90-225
	CAMBRIAN		Sawatch Qtzt.	0-20
PRECAMBRIAN				

Figure 4. Generalized stratigraphic column for south-central Colorado

Pennsylvanian and Permian

Orogenic activity manifested itself in Pennsylvanian and Permian time in the central United States with the vigorous uplift of the Ancestral Rocky Mountains. In central Colorado, these mountains consisted of two northwest-southeast trending highlands known as the Front Range Highland and the Uncompahgre Highland. These uplifts were separated by a narrow depositional basin, the Central Colorado Trough, a feature which has also been described as a graben (DeVoto and Peel, 1968). The study area was located on the eastern flank of the Uncompahgre Highland and was cleaved in two by its southeastern boundary, the Pecos-Picuris fault (Fig. 5).

A mixture of fluvial sediments grading upward into shallow-water carbonates dominated initial sedimentation in the Central Colorado Trough. By Atokan time, pronounced uplift of the Uncompahgre Highland resulted in the exposure of the Precambrian crystalline basement and the widespread deposition of red arkosic alluvial deposits within the Central Colorado Trough (DeVoto and Peel, 1972). Relief on this Pennsylvanian uplift may have been as great as 3 km (Mallory, 1972). Late Pennsylvanian deposits were largely influenced by this earlier faulting, with thicknesses varying laterally along the trough. Rocks of this age indicate a shallow coastal plain environment (DeVoto et al., 1971).

Renewed uplift of the Uncompahgre Highland in early Permian time drastically changed sedimentation in the adjacent

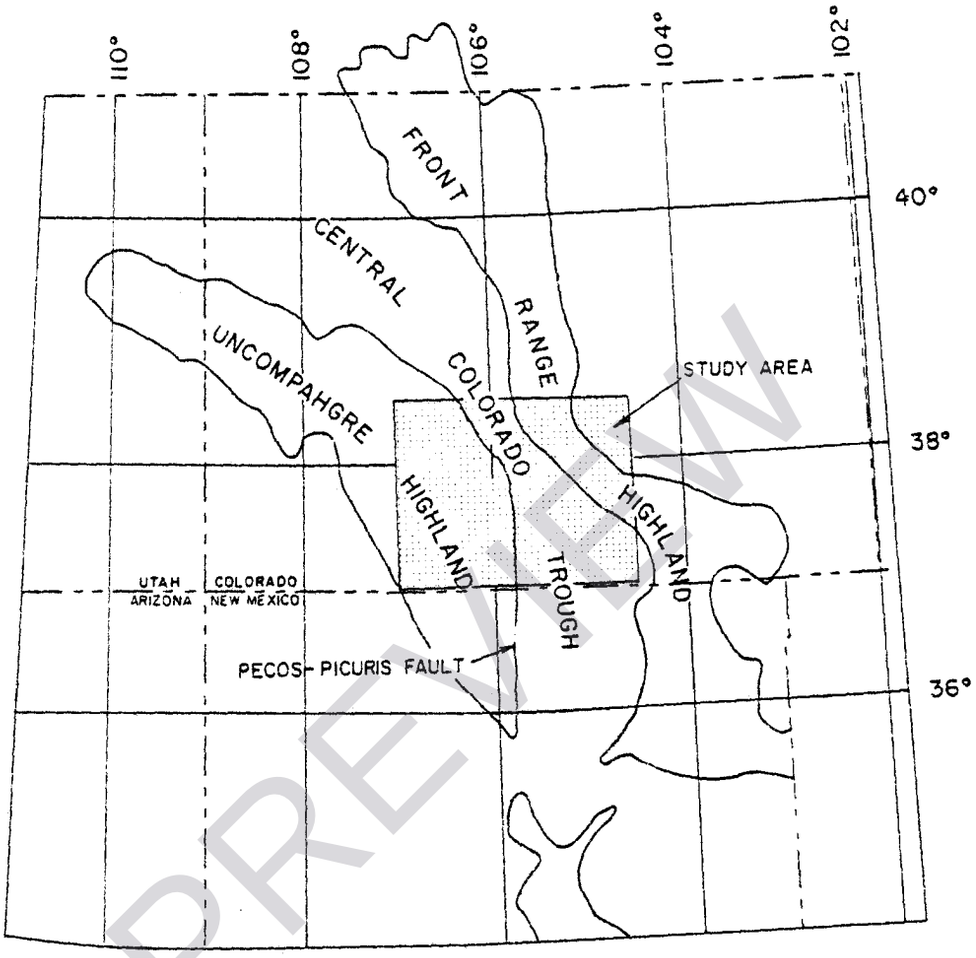

Figure 5. General outline of major Pennsylvanian and Permian highland areas in Colorado

basin. Rapid erosion of the rising Precambrian massif developed thick deposits of continental arkosic sandstones and conglomerates. Repeated movements along the bounding fault(s) triggered periods of vigorous erosion of the upland, thereby imparting a cyclic character to the deposits. Deformation of this nature continued until late Permian time when the basins, filled with detritus, encroached on the adjacent uplifts and reduced their topographic relief (DeVoto and Peel, 1968). In all, an average of 4500 meters of Pennsylvanian and Permian sediments were deposited in the Central Colorado Trough.

Mesozoic

Rocks of Mesozoic age do not occur in the San Luis Valley. However, the presence of a thick Mesozoic section in the neighboring Raton Basin and the San Juan Mountains, as well as scattered outcrops in the southern Wet Mountains and central Sangre de Cristo Range (Baltz, 1965), indicate that Mesozoic sediments once covered the study area but have been removed by widespread erosion associated with uplift of the region during the late Cretaceous-early Tertiary Laramide orogeny (Knepper and Maars, 1971).

At the close of Permian time, the once-towering uplifts of the Ancestral Rocky Mountains existed only as erosional remnants. Regional stratigraphic evidence supports the existence of these remnants until late Jurassic time when Morrison age, continental fluvial sediments finally buried them (Oriel