AN INTEGRATED GEOPHYSICAL ANALYSIS OF THE GREAT DIVIDE BASIN

AND ADJACENT UPLIFTS, SOUTHWESTERN WYOMING

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by

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THESIS

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ABSTRACT

The integrated analysis of this study, which relies heavily on the seismic reflection profiles released by Chevron USA, Inc., provides several new insights about the deep structure of the Great Divide basin and adjacent uplifts in southwestern Wyoming. A geologic cross–section constructed from 2 1/2 dimensional gravity models constrained by seismic reflection data, illustrates relationships between the Laramide thrusting and heterogeneity in the Archean basement. Spatial relationships evidenced by the overlay images (gravity and Landsat TM) provide additional information that corroborates previous studies.

A cross–sectional model based on the gravity models supports a maximum dip of 45° to the northeast for the Wind River thrust. This supports previous studies based on the COCORP deep seismic reflection line. A shallower dip for the Emigrant Trail thrust is displayed in the cross–section. The model also displays approximately 10 km of underlying sediments beneath the Wind River thrust.

The seismic lines that lie approximately on the gravity profile of the cross–sectional model depict inhomogeneities in the Archean basement in this area that have not been previously recognized. The inhomogeneity of the basement is also evidenced by varying the density of the basement in the gravity model. The cross–sectional model derived from the gravity profile also provides information about the nature and location of the zones of thrusting, which is coincident with an area of inhomogeneity in the Archean basement.

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INTRODUCTION

Most of Wyoming lies within the Rocky Mountain foreland basin of western North America which is bounded by the Cordilleran fold and thrust belt on the west and the stable North American craton on the east. The Wyoming foreland basin has been one of the major hydrocarbon producing regions in North America because of the combination of ideal sedimentary sequences and a complex tectonic history (Gries et al., 1992). This study focuses on southwestern Wyoming, and is part of the ongoing research at the Pan American Center for Earth and Environmental Studies (PACES) and a larger investigation of the crustal structure of the southern Rocky Mountains that extends from southern Wyoming to northern New Mexico (the Continental Dynamics Rocky Mountains Project; CD–ROM).

The region of study lies east of the Wyoming–Idaho–Utah fold and thrust belt or Overthrust belt, extending into southern Fremont and northern Sweetwater Counties (Figure 1). The major structural features within the area of interest are the Wind River uplift, the Sweetwater uplift, the Rock Springs uplift and Great Divide basin. Many authors refer to the structural feature known as the Sweetwater uplift as the Granite Mountains, a physiographic feature. Throughout this study a distinction will be made when referring to this feature. Sweetwater uplift will be used to refer to the structural feature and Granite Mountains will be used to refer to the topographic feature.

Various tectonic events have played a role in the development of the structural features in the area, two of which were the Sevier (≈140 to 80 Ma) and Laramide (≈80 to 36 Ma) orogenies (Gries et al., 1992). These two events produced different styles of

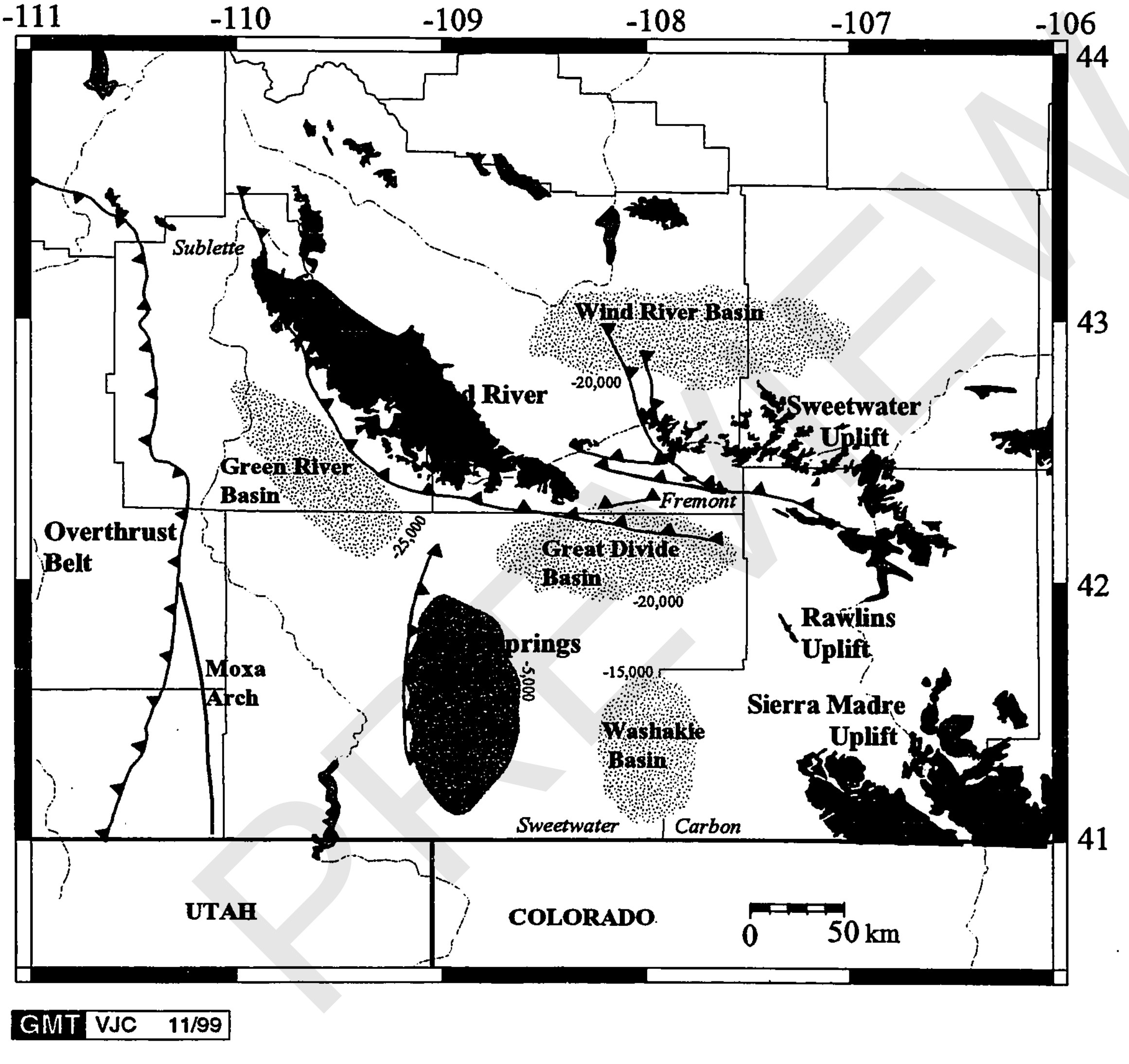

Figure 1: Laramide basement uplifts (Precambrian outcrops depicted in pink) and basins (deepest part depicted in purple). In each basin, the approximate maximum depth (ft) of the Precambrian basement below sealevel is shown.(adapted from Blackstone, 1991).

deformation. Low–angle, continuous sled–runner type thrusts characterize the deformation associated with the Sevier orogeny. Episodic Laramide deformation of the crust resulted in basement involved thrust faults, of a generally higher angle than Sevier thrusts, and associated folding of sediments (Gries, 1983b). The role of Wyoming's complex Archean history upon the development of the major structural features in the study area has not been fully documented and is one target of this study.

The evolution of the basins and uplifts associated with the Laramide orogeny has been difficult to understand because of the episodic nature of this orogeny and the presence of varying stress orientations present (Brown, 1993; Erslev, 1993; Perry et al., 1990; Brown, 1988; Gries, 1983a). Uplifts in the region have orientations ranging from north–south, northwest–southeast, and west–east as a result of the varying stress field and structural complexities (Figure 1). Within the study area three uplifts: the north–south trending Rock Springs uplift, the northwest trending Wind River uplift and the west–east Sweetwater uplift occur. These uplifts are bounded by hydrocarbon producing basins: the Green River basin, Wind River basin, Great Divide basin and Washakie basin (Erslev, 1993).

Numerous geologic and geophysical studies have been undertaken to unravel the tectonic history of the Rocky Mountain foreland basin (Erslev, 1993; Brown, 1993; Stone, 1993; Robbins and Grow, 1990). Each has utilized a geologic or geophysical technique to develop conclusions about the structural evolution of this area. The objectives of this study are: 1) to determine the upper–crustal structure of the area of interest by constructing cross–sectional models along seismic profiles that were released for this study, 2) examine

the control of older structures on the Laramide evolution of the region and 3) use spatial data (gravity and Landsat TM) to extrapolate away from the control provided by the seismic profiles. Previous investigations of the Wind River uplift will be incorporated to aid in the understanding of the geologic evolution of this tectonically complex region. An integrated geophysical approach utilizing two–dimensional unmigrated seismic reflection data, gravity data, borehole data and Landsat TM imagery will be employed in this study.

GEOLOGIC BACKGROUND

Overview

The region of interest for this study lies within the Rocky Mountain foreland basin of southwestern Wyoming. Subsidence of this basin was caused by both tectonic loading and the redistribution of the load by erosion and deposition. Intrabasinal structures are thought to have developed as early as Maastrichtian time and continued with Laramide deformation which included basement uplifts and subsidence of intermontane basins (Steidtmann, 1993). Timing of uplifts is based upon distribution of Middle to Late Cretaceous sediments. Sedimentary rocks within the basins range in age from Cambrian to Tertiary, excluding Silurian rocks (Snoke, 1993). Thicknesses and descriptions of major stratigraphic units from Cambrian to Cretaceous in western Wyoming were obtained from Blackstone (1991) and are included in Figure 2.

The Rocky Mountain foreland basin of Wyoming was formed as the North American lithosphere migrated westward and overrode the subducting Farallon lithosphere (Figure 3). In the interior of the North American plate, the Cordilleran fold and thrust belt formed about 140 Ma in response to convergence at the margin (Gries et al., 1992). At approximately 75 Ma, convergence accelerated and the subducting plate became more gently dipping. Crustal shortening during the Laramide produced asymmetric anticlines involving Precambrian basement rocks bounded on one or both sides by reverse faults or monoclinal structures (Figure 4). Deep basins subsided concurrently with the rise of the uplifts (Hamilton, 1988).

Geologic Age	Formation Name	Lithology	Thickness (ft)
CRETACEOUS	Lance	Sandstone - white, gray buff; shale/claystone; coals	0 (?)
	Fox Hills	Sandstone - buff to light gray, fine- to medium-grained	0-150
	Lewis	Shale - dark gray, soft,interbedded with thin sandstone beds	(?)
	Mesaverde	Sandstone - gray and brown,fine- to medium-grained; some thin carbonaceous layers and coals	1000
	Cody	Shale - gray, limy in lower part; thin persistent shales in upper part	4000 +
	Frontier	Sandstone - gray and brown, more abundant in upper part; bentonite and tuff beds in lower part	800-900
	Mowry	Shale - black, weathering to silver gray, hard,siliceous, abundant fish scales	250-300
	Thermopolis	Muddy Sandstone Member: sandstone - gray to brown, medium-grained; black shale partings	40-75
		Lower Member: shale - black, soft, sandy near base	140
CRETACEOUS AND JURASSIC	Cloverly	Sandstone - sandstone and thin conglomerate; variegated claystones	350-400
	Morrison	Sandstone - gray, silty; interbedded dull claystones	
JURASSIC	Sundance	Upper part: pale green and brown, abundant glauconite; sandy glauconitic limestones	115-150
		Lower part: sandstone - gray, very fine-grained; thin, fossiliferous limestones	75-100
	Gypsum Spring	Anhydrite (gypsum on outcrop) at base; red siltstones and red shales above	0-150
	Nugget	Sandstone - salmon red, medium-grained, crossbedded rounded quartz grains	400-525
	Chugwater	Popo Agie Member: siltstone and claystone - purple, red, ocher	235 (?)
		Crow Mountain Member: sandstone - salmon red, crossbedded	50-100
		Alcove Member: limestone - purple gray, thinly bedded	2-10
		Red Peak Member: siltstone and shale - brick red, soft	800-900
TRIASSIC	Dinwoody	Siltstone - brown, dolomitic, hard	50-100
PERMIAN	Phosphoria	Dolomite - tan, petroliferous, thin sandstones; bedded chert	275-325
PENNSYLVANNIAN	Tensleep	Sandstone - white to gray, fine-grained, crossbedded; thin dolomite beds	250-300
PENNSYLVANNIAN AND MISSISSIPPIAN	Amsden	Shales - red and green; thin, dense, white dolomite	260-300
		Darwin Sandstone Member: sandstone - red and gray	0-50
MISSISSIPPIAN	Madison	Limestone - white to blue-gray, in part dolomitic, hard, cherty	400-500
DEVONIAN	Darby (?)	Dolomite - thin, brown, petroliferous,if present	?
ORDOVICIAN	Bighorn	Dolomite - gray to tan, hard, siliceous, massive; chert beds locally	0-50
CAMBRIAN	Undifferentiated	Limestone - brown to gray, glauconitic in upper part; red and brown sandstone in lower part	900-1000
PRECAMBRIAN		Gneisses, schists, and iron formation; granitic intrustion	

Figure 2: Stratigraphy of Phanerozoic sediments from Cambrian to Cretaceous (adapted from Blackstone, 1991).

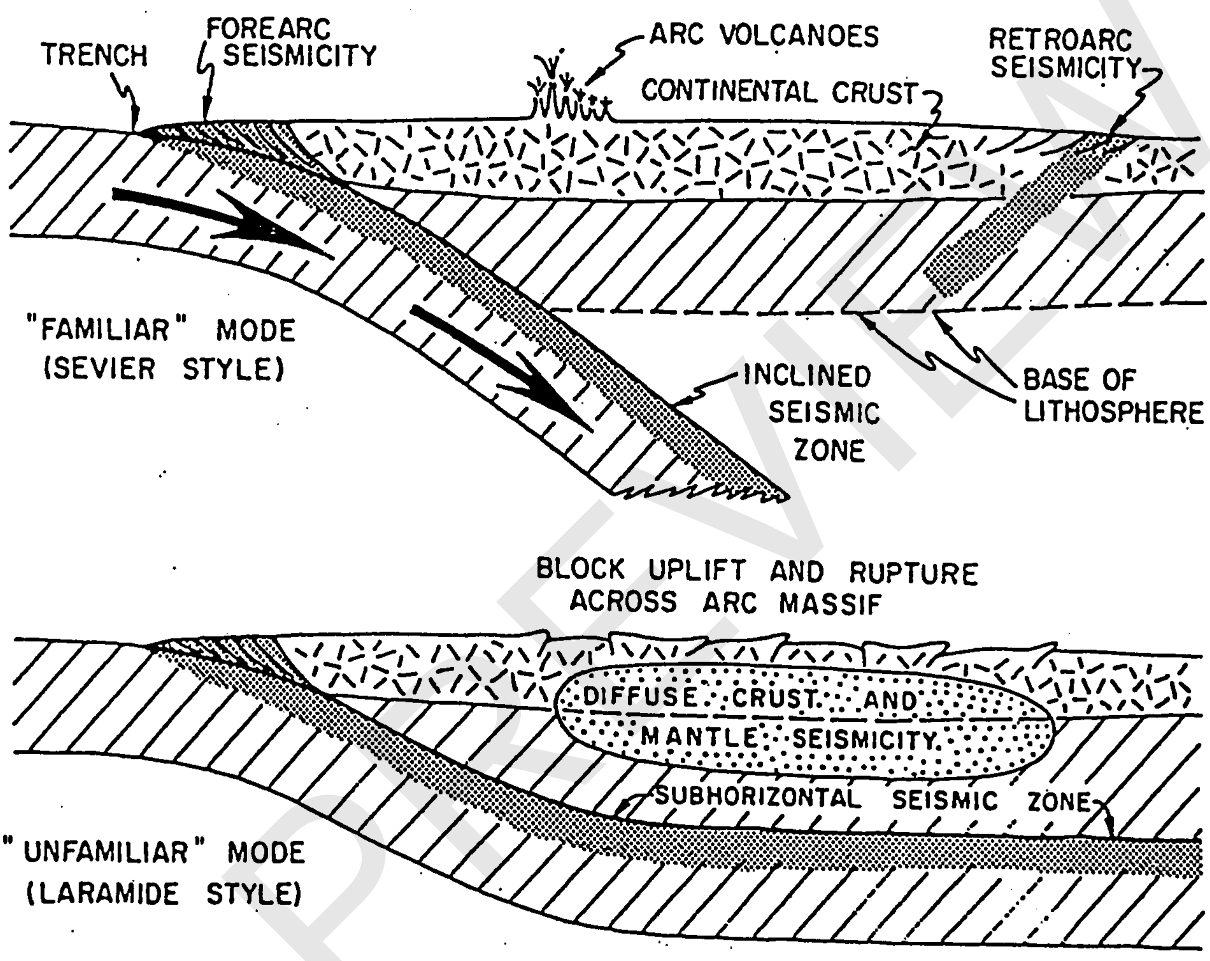

Figure 3: Schematic cross sections contrasting normal vs. flat–plate subduction (from Dickinson and Snyder, 1978).

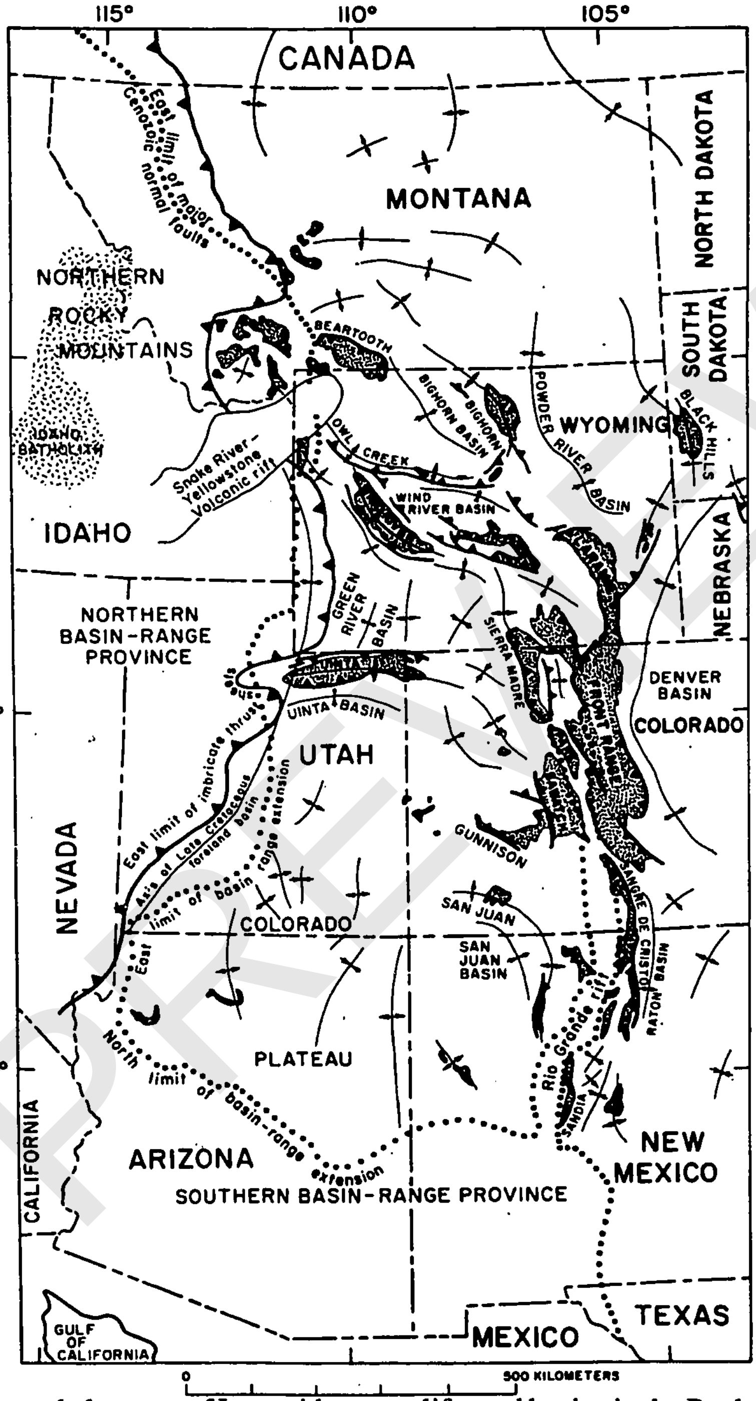

Figure 4: Structural elements of Laramide age uplifts and basins in the Rocky Mountain region. Outcrops of Precambrian rocks east of the foreland fold and thrustbelt and north of the southern Basin and Range province are shaded (from Hamilton, 1988).

Laramide crustal shortening is most commonly attributed to basal shear between the North American plate and the subducting Farallon plate (e.g. Dickinson and Snyder, 1978). An episode of extensional tectonics occurred after Tertiary deposition producing normal listric faults with the same attitude as the reverse fault which they are associated (Blackstone, 1991).

Precambrian

Precambrian basement rocks in southwestern Wyoming are part of the Archean Wyoming province (Frost and Frost, 1993; Snoke, 1993) (Figure 5). Figure 6 is a Precambrian outcrop and structural configuration map from Blackstone (1991). The extent of the Wyoming province is thought to be much larger than is exposed today (Figure 5). The eastern and southern boundaries are defined by the Trans–Hudson orogenic belt and the Colorado Proterozoic province respectively. The western and northern boundaries are less well defined. The western boundary is thought to extend to the East Humboldt Range of northeastern Nevada based on geochemical and isotopic characteristics. A geophysical anomaly in Alberta, Canada interpreted to be a graben or suture between the Hearne and Wyoming provinces may delineate the northern extent of the Wyoming province (Houston, 1993). A recent deep seismic investigation delineated the northern boundary by a decrease in Moho depth from ≈ 50 km to ≈ 40 km going from the Wyoming to Hearne province (Deep Probe Working Group, 1998).

The Wyoming province is petrologically heterogeneous consisting of both metamorphic and igneous complexes (Figure 7, Houston, 1993; Frost and Frost, 1993; Ray

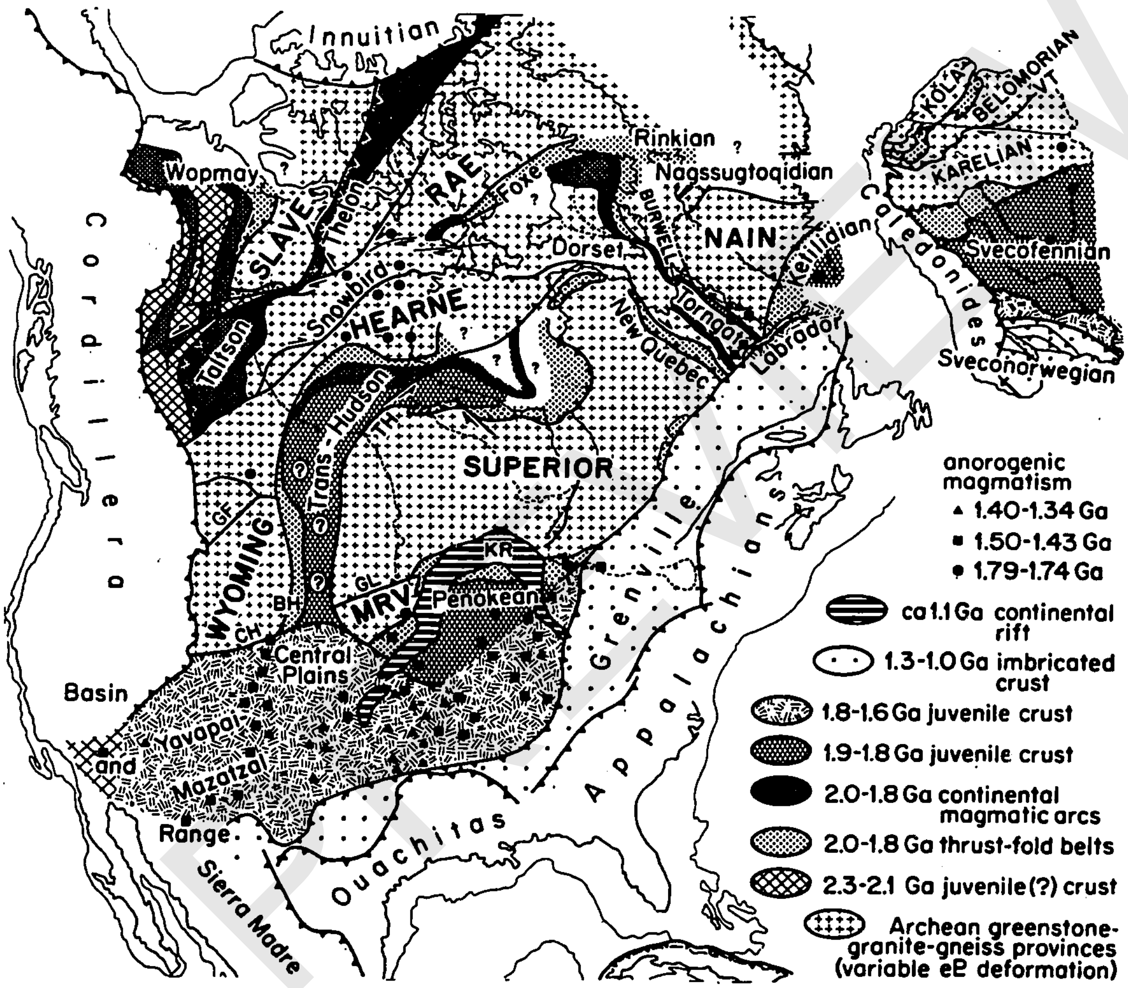

Figure 5: Position of the Archean Wyoming province relative to other Precambrian–age belts and 1.4 to 1.5 Ga magmatism. The platform cover of the North American craton has been removed. Upper–case names are Archean provinces; lower–case names are Proterozoic and Phanerozoic orogens. BH, Black Hills inlier; CH, Cheyenne belt; GF, Great Falls tectonic zone; KR, Keweenawan rift; MRV, Minnesota foreland (taken from Snoke, 1993).