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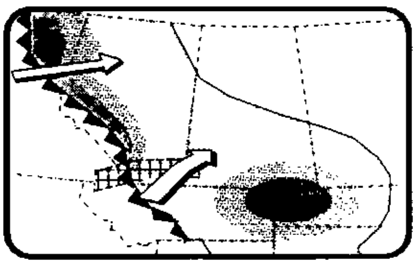

Contrasting Character of the Peace River and Sweetgrass Arches, Western Canada Sedimentary Basin

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Introduction

Arches are large positive structural features that occur either within or bordering sedimentary basins. They are characterized by their spatial orientation relative to a sedimentary basin, and by the nature and timing of the deformation associated with them. Variations in sedimentary rock thickness and facies across an arch, within specific time segments, can be used to deduce the general tectonic history of that feature.

The Peace River and Sweetgrass Arches are predominantly intra-basinal features that trend perpendicular to the depositional strike of the Western Canada Sedimentary Basin (Figure 1). The Sweetgrass Arch separates two sub-basins, the Alberta and Williston Basins (Figure 1). Both Arches are zones of crustal weakness that may be the loci of metallic mineralization in the subsurface of Western Canada.

Peace River Arch

The Peace River Arch strikes east from the Laramide deformed belt into the northern part of the relatively undeformed Alberta Basin (Figure 1). It is a discrete entity that underwent several periods of epeirogenic movement accommodated by block faulting (Figure 2), local folding, and regional flexure.

Interpretation of the pre-Devonian tectonic history is difficult because early Paleozoic erosion has removed pre-Devonian sedimentary rocks in the Peace River region. The earliest deformation may have formed a late Precambrian epicratonic trough, similar to the Belt Basin and Uinta Trough in the western United States (Stewart, 1976), and the southern Alberta rift (Figure 1) (Kanasewich *et al.*, 1969). There is evidence for thickness and facies changes in younger late Precambrian sedimentary rocks along the extension of the Peace River Arch into the Laramide deformed belt (Stelck *et al.*, 1978; G.C. Taylor, pers. comm., 1987), though there is disagreement as to whether these patterns imply that the region was a trough or an arch at this time. Facies patterns in Middle Cambrian rocks of the Alberta Basin indicate that the Peace River region probably was a positive structural element during this time (Pugh, 1973).

The most significant period of epeirogenic uplift took place in the latest Silurian to Middle Devonian time. Middle and Upper Devonian rocks were deposited directly on the Precambrian crystalline basement (Figure 3) of this topographic highland (de Mille, 1958). Block faulting and regional flexure accommodated the uplift (Figure 2). Progressive onlap with time deposited successively younger carbonate reef tracts which partly surrounded the Arch. The thickest and most continuous of these is the Leduc reef tract, which outlines the early Paleozoic core of the Arch (Figure 2).

The Arch began to subside in Famennian time and by Early Carboniferous time had collapsed by regional flexure and block faulting into a basinal area with thicker (Figure 3), deeper water facies than in the surrounding Alberta Basin (Lavoie, 1958). The period of greatest subsidence occured in the latest Early Carboniferous, typically underlain in the area by the early Paleozoic core of the Arch (Zolnai, 1986). The preserved edge of the Stoddart Group almost mimics the depositional edge of the Devonian Leduc reef tract (Figure 2).

The Peace River region may have been episodically uplifted in the Permian and Mesozoic (Lavoie, 1958), but probably remained, for the most part, a subtle basin until latest Cretaceous to Tertiary times, when Laramide deformation again formed an Arch (Williams, 1958). There are no thickness changes in major Mesozoic depositional units across the region (Figure 3), though subtle facies changes parallel to the trend of the Arch suggest that minor epeirogeny occurred in the Mesozoic.

The subsurface Peace River Arch is an important oil- and gas-producing region (Figure 2), but does not have any discovered metallic mineral deposits (Alberta Chamber of Resources, 1987). Hydrocarbons occur in structural and structural-stratigraphic traps in Upper Paleozoic and Mesozoic reservoir rocks (Figure 2). Metallic mineral deposits are most likely to occur in Devonian or Mississippian carbonate host rocks along fault-

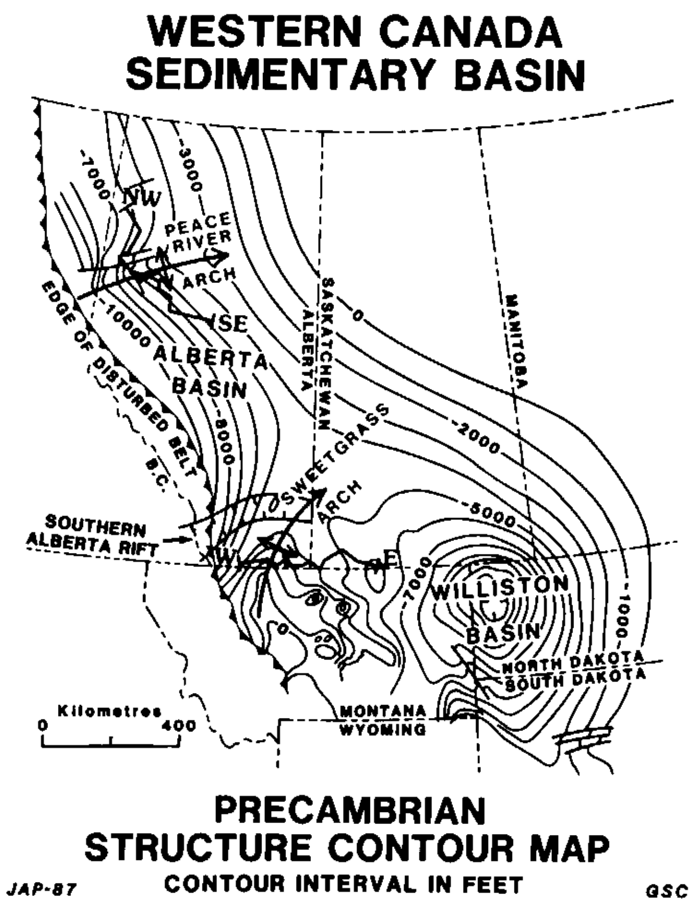

Figure 1 *Precambrian structure contour map, Western Canada Sedimentary Basin. (After Burwash* et al., *1964 and RMAG Research Committee, 1967-1969, 1972).*

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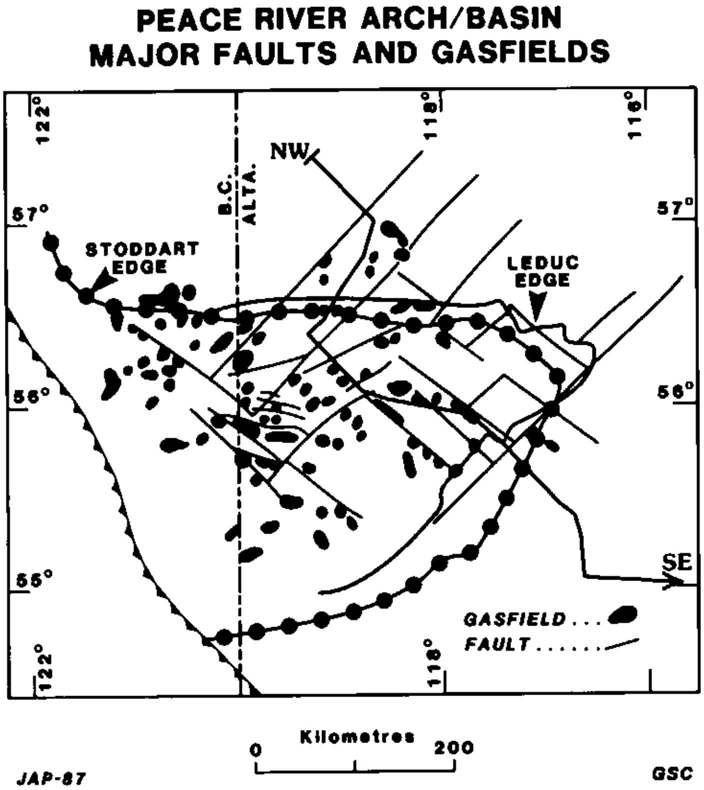

Figure 2 *Peace River Arch/Basin, major faults and gas fields. Northwest-southeast line of section shown. Leduc and Stoddart edges outline core of the Arch.*

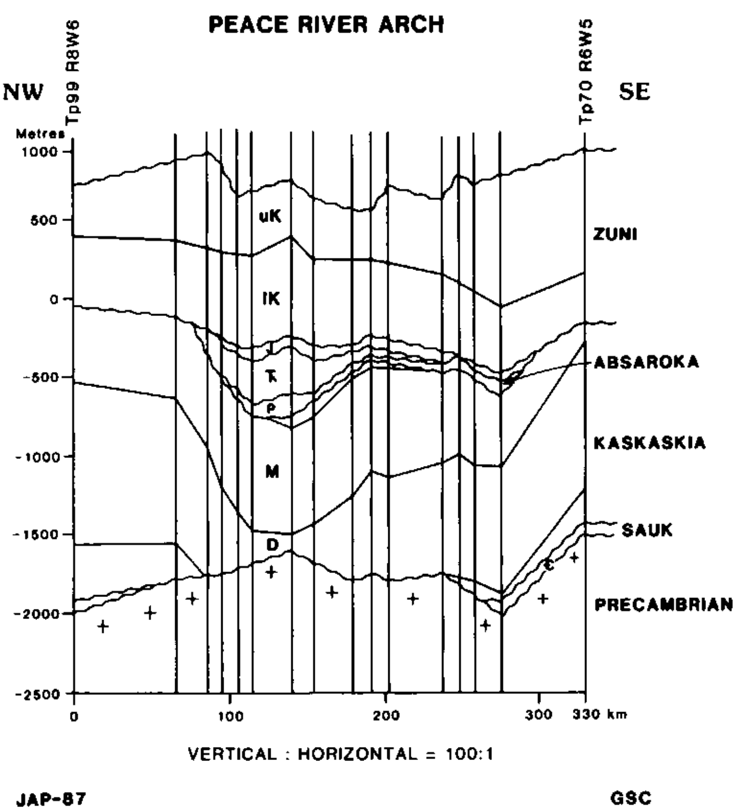

Figure 3 *Northwest-southeast section across Peace River Arch. Only major depositional units shown. Sloss (1963) sequences on right for comparison purposes. C, Cambrian; D, Devonian; M, Mississippian; P, Permian; T, Triassic; J, Jurassic; lK, Lower Cretaceous; uK, Upper Cretaceous.*

fracture zones, in situations genetically similar to the Pine Point lead-zinc deposits of the Northwest Territories. Families of metallic mineral deposits related to igneous activity probably do not occur, as no plutonic or volcanic rocks are known in this region. A surficial Upper Cretaceous sedimentary iron deposit (Mellon, 1962) probably has several comparable subsurface deposits, but is not genetically related to the Peace River Arch.

Sweetgrass Arch

The Sweetgrass Arch in southern Alberta and northwestern Montana (Figure 1) consists of several components, including: broad arches; tight, northwest-trending, north-plunging, faulted folds; and local domal features. The principal components are the three broad arches shown in Figure 4. They include: the northwest-plunging South Arch; the northwest-striking Kevin-Sunburst Dome; and the northeast plunging Bow Island Arch that separates the Alberta and Williston Basins in Canada. The South Arch and Kevin-Sunburst Dome are discrete entities, separated by the Pendroy Fault Zone, that underwent several stages of epeirogenic movement during the Cambrian, Jurassic, Cretacous, and Paleogene periods (Arnott, 1987; Peterson, 1985). The latest movements were caused by Laramide compression and shearing following formation of a Jurassic forebulge by lithospheric flexure (Lorenz, 1982). The Bow Island Arch, however, was not a positive feature prior to the Laramide, except perhaps in the Jurassic (Hayes, 1983). Early Cretaceous erosion of Jurassic strata has masked the Jurassic depositional limits in southern Alberta, but facies patterns suggest that the Bow Island Arch was a broader, lower amplitude feature than the Paleogene Arch. It is evident from Figure 5 that no major depositional or erosional thinning occurred across southern Alberta, except in the Tertiary. Subtle facies changes that do occur within Phanerozoic strata cannot be correlated to the present Bow Island Arch. In addition, structure contours shown in Figures 1 (Precambrian) and 4 (Colorado Group) are similar to each other and to contours on all horizons in southern Alberta. Most of the evidence points to only Paleogene uplift of the present Bow Island Arch relative to the Alberta and Williston Basins.

The northwest- to north-trending, tight, faulted anticlines that plunge northward from Kevin-Sunburst Dome (Figure 4) are probably Laramide features, related to the deformed belt to the west. Their temporal relation to the Bow Island Arch is unknown, though they change orientation from northwest to north as they approach this feature (Tovell, 1958).

The local domal features in the entire region of the Sweetgrass Arch (Figure 4) have several origins, all of which are unrelated to, but may have been subsequently affected by, the formation of the Arch. One type is Precambrian to Early Paleozoic erosional monadnocks probably related to a tectonic or plutonic process, that may have been tectonically reactivated through later Phanerozoic time. A second type is formed by local multi-stage salt solution (Smith and Pullen, 1967; Swenson, 1967), that may also have several epeirogenic events associated with it. A third, rare type is formed by meteorite impact in the Phanerozoic (Sawatzky, 1976). The fourth, and possibly the most common type of domal structure, is formed by Eocene, alkalic, hypabyssal intrusions, that are concentrated on the east flank of the Kevin-Sunburst Dome (Lageson, 1985; Marvin *et al.*, 1980). The Sweetgrass Hills in northern Montana are the only surface exposures of these intrusions.

Significant gas and oil reserves occur in structural-stratigraphic traps in the Devonian, Carboniferous, Jurrasic and Cretaceous section of the Sweetgrass Arch region of southern Alberta and northern Montana. In addition, carbon dioxide and inert gases occur in Cambrian and Devonian rocks in the Kevin-Sunburst Dome (Wennekers, 1985) and in local domal features (Burwash and Cumming, 1974). Metallic minerals have not been discovered in the surface or subsurface of the Canadian portion of the Sweetgrass Arch (Alberta Chamber of Resources, 1987). In the Sweetgrass Hills of Montana, however, contact aureoles in Mississippian carbonates surrounding the Eocene intrusions contain copper and iron sulphides with gold and silver (Rice and Meldahl, 1966). Similar contact zones may also occur in the subsurface of Alberta, to depths of 2000 m. Other subsurface metallic mineral occurrences may be associated with fault zones in, and contact aureoles surrounding, Tertiary plutonic rocks, similar to those of the Little Rocky Mountains in Montana (Dyson, 1953); or Precambrian plutonic rocks, similar to those described by Burwash and Cumming (1974). Plutons of either age have not yet been identified in southern Alberta.

Conclusions

The Peace River and Sweetgrass Arches are two intra-basinal features that differ in most aspects of their development. The Peace River Arch is a relatively stationary (through time), single-component, block-faulted feature that was an arch in the Early Paleozoic, a basin in Late Palezoic and Mesozoic, and a subtle arch from latest Mesozoic to the present. The Sweetgrass Arch has several components, each of which has a unique history and style of deformation. The Canadian portion, the Bow Island Arch, is a broad Paleogene flexure that separates the Alberta and Williston Basins. The only ancestral (Pre-Paleogene) Bow Island Arch existed in the Jurassic, but probably had a different spatial configuration. Smaller northwest-plunging anticlines in southwestern Alberta are probably Laramide features related to the

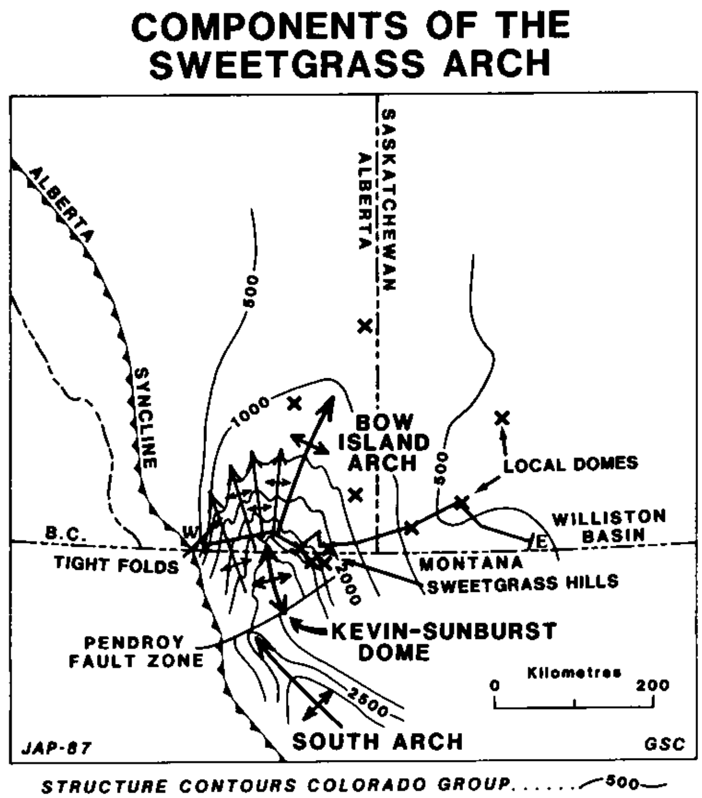

Figure 4. *Components of the Sweetgrass Arch. West-east line of section shown. (After Dobbin and Erdmann, 1955; McLean, 1971; and Tovell, 1958).*

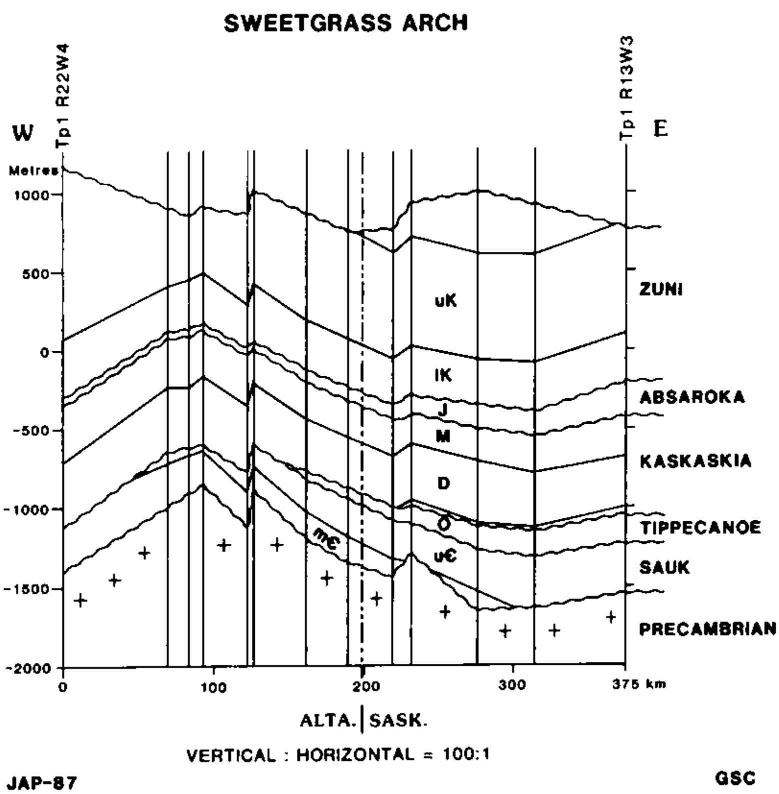

Figure 5. *West-east section across Sweetgrass Arch. Only major depositional units shown. Sloss (1963) sequences on right for comparison purposes.* ***MC****, Middle Cambrian;* ***UC****, Upper Cambrian;* ***O****, Ordovician;* ***D****, Devonian;* ***M****, Mississippian;* ***J****, Jurassic;* ***lK****, Lower Cretaceous;* ***uK****, Upper Cretaceous.*

deformed belt in the west and the large Kevin-Sunburst Dome and South Arch in Montana.

There are no discovered deposits of metallic minerals in the subsurface of either region. The best potential in the Peace River Arch district is in lead-zinc deposits similar to Pine Point: in the Sweetgrass Arch district it is in copper and gold deposits similar to those in the Sweetgrass Hills and Little Rocky Mountains. In all cases, it is extremely unlikely that a subsurface deposit will be discovered that would be economically viable in the near future.

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