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Introduction and Overview

By Jules D. Friedman *and* A. Curtis Huffman, Jr.

Three well-known laccolith complexes of southeastern Utah, the Henry, La Sal, and Abajo Mountains, have similar petrogenesis, tectonic control, and lithophile hydrothermal mineralization. These complexes were the principal subjects of a U.S. Geological Survey sponsored workshop on July 6 and 7, 1992, in Denver, Colo., convened by Jules D. Friedman and A. Curtis Huffman, Jr. The purpose of the workshop was to present and clarify new field and laboratory data in order to (1) provide an analog for Cordilleran laccolith fields on intracratonic blocks; (2) narrow the age range of Colorado Plateau laccoliths by consideration of errors in earlier dating attempts in relation to recent high-precision $^{40}Ar/^{39}Ar$ and fission-track dates; (3) relate distribution of southeastern Utah intrusive centers to tectonics and structures; (4) associate emplacement of laccolith complexes on the Colorado Plateau with specific tectonomagmatic events and possible thermal events of the mantle; and (5) define possible economic ore-deposit implications. This report summarizes much of the material presented at the workshop and provides an extensive list of selected references pertaining to geochronology and tectonics of the Colorado Plateau to facilitate further research.

Eugene Shoemaker (USGS) set the stage for a discussion of tectonic control of the laccolith complexes by presenting evidence for Precambrian movement on northeast- and northwest-trending discontinuities in the Grand Canyon region that extend into southeastern Utah. Movement on the northeast-trending set, including the Bright Angel and Sinyala fault zones, was earlier than that on the northwest-trending systems. Geophysical and subsurface data presented by Richard Blank (USGS) and William Butler (USGS) support the importance and regional nature of the northeastern and northwestern trends. Northwesterly structural trends of the Paradox and Uncompahgre fault zone and basement uplift are strongly expressed in both magnetic and isostatic gravity data, whereas the northeast-striking fault systems that enter the region from northern Arizona are somewhat less so. The gravity data indicate that the most known or geophysically inferred laccolithic centers are on the margin or noses of basement uplifts.

Recent field mapping in the southern Henry Mountains by Marie Jackson (USGS) reaffirms that the major intrusive bodies of southeastern Utah are true laccoliths, floored at shallow depths. Her structural analysis indicates that the Oligocene stress field in the vicinity of the Henry Mountains laccoliths was isotropic. Field mapping and structural analysis of the La Sal Mountains by Michael Ross (UGS) and the Paradox fold and fault belt by Helmut Doelling (UGS) indicate that the northwest-striking faults that control the Paradox Valley–Castle Valley–Salt Valley salt diapirs are possibly connected by a northeast-striking fault zone or ramp-monocline structure forming a kink in the tectonic boundary between two parts of the Late Paleozoic Paradox Basin. The La Sal intrusions were emplaced at the intersection of these fault systems.

Whether the other laccolith complexes were emplaced at similar nodes in an orthogonal northwest-northeast fault grid is not nearly as certain although it seems likely, and this hypothesis appears to be supported by correlation of northeasterly and northwesterly lineament trends evident in remote sensing, geologic, and geophysical data discussed by Jules Friedman (USGS). This argument is further strengthened by demonstrated episodic movement on both northeast- and northwest-striking basement faults that are part of an orthogonal grid mapped in the San Juan and Paradox Basins by Curtis Huffman (USGS) and David Taylor (USGS) using reflection seismic data. Movement on some of these faults influenced deposition of sediments throughout the Phanerozoic. Earl Verbeek (USGS) and Marilyn Grout (USGS) documented local control of joints by basement faults but went on to point out that widely distributed post-Laramide regional joint sets commonly developed independent of basement control.

Petrologic studies by Stephen Nelson (UCLA) and Jon Davidson (UCLA) indicate that all three laccolith complexes are petrogenically bimodal but proportionately variable; these quartz monzonite porphyries probably evolved from mantle-derived magma ponded in the deep crust. New high precision $^{40}Ar/^{39}Ar$ and fission-track ages reported by Nelson and Davidson and by Kim Sullivan (Brigham Young University) place the southeastern Utah intrusive activity

during the interval from 31.2 to 23.3 Ma, hence late Oligocene to early Miocene. The laccoliths are thus partly correlative with much of the late Oligocene to early Miocene volcanic belt that extends 1,100 km sublatitudinally from western Nevada through southern Utah to southwestern Colorado, and from there south to west Texas. Charles Chapin and William McIntosh (both New Mexico Bureau of Mines and Mineral Resources) and coworkers pointed out that the laccolith clusters of southeastern Utah were emplaced during the second of two major episodes of ash-flow volcanism in the Mogollon-Datil volcanic belt within this vast region (this paper is not included in this proceedings volume).

Peter Rowley (USGS), Charles Cunningham (USGS), Tom Steven (USGS) and coauthors demonstrated that the calc-alkaline intrusive rocks of the Pioche-Marysvale and Delamar–Iron Springs igneous belts (in southwestern Utah and southeastern Nevada) are generally similar in age and composition to the laccolith complexes of southeastern Utah and to most other parts of the sublatitudinal igneous province that spans the Great Basin, Colorado Plateau, and adjacent areas. Nelson, Davidson, Rowley and coauthors inferred that the calc-alkaline magmas of mostly intermediate composition probably evolved from mantle-derived basaltic magmas emplaced into the deep crust and modified by fractional crystallization and subordinate assimilation of crustal components; crustal melting (or, alternatively, large-scale assimilation by mantle-derived magmas, according to other workers) may have formed younger silicic rocks in the province. They concluded that the Oligocene and Miocene calc-alkaline part of the igneous province probably originated by subduction of oceanic lithosphere beneath western North America and that east-northeast extensional deformation accompanied the magmatism.

The workshop ended on a thought-provoking, enigmatic note with the suggestion by Felix Mutschler (E. Washington Univ.) and coauthors Edwin Larson (Univ. of Colorado) and David Gaskill (USGS, Ret.) that the Colorado Plateau is an isolated block of Proterozoic craton that was reduced in size by the lateral encroachment of a series of Late Cretaceous to Holocene *passive* hotspots. They also see a modest potential for alkaline-rock related gold mineralization in all of the laccolith complexes, a point that was also made by Michael Ross (UGS) in relation to the La Sal Mountains.

No attempt was made by the coordinators to achieve a consensus on controversial points presented by different authors.

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