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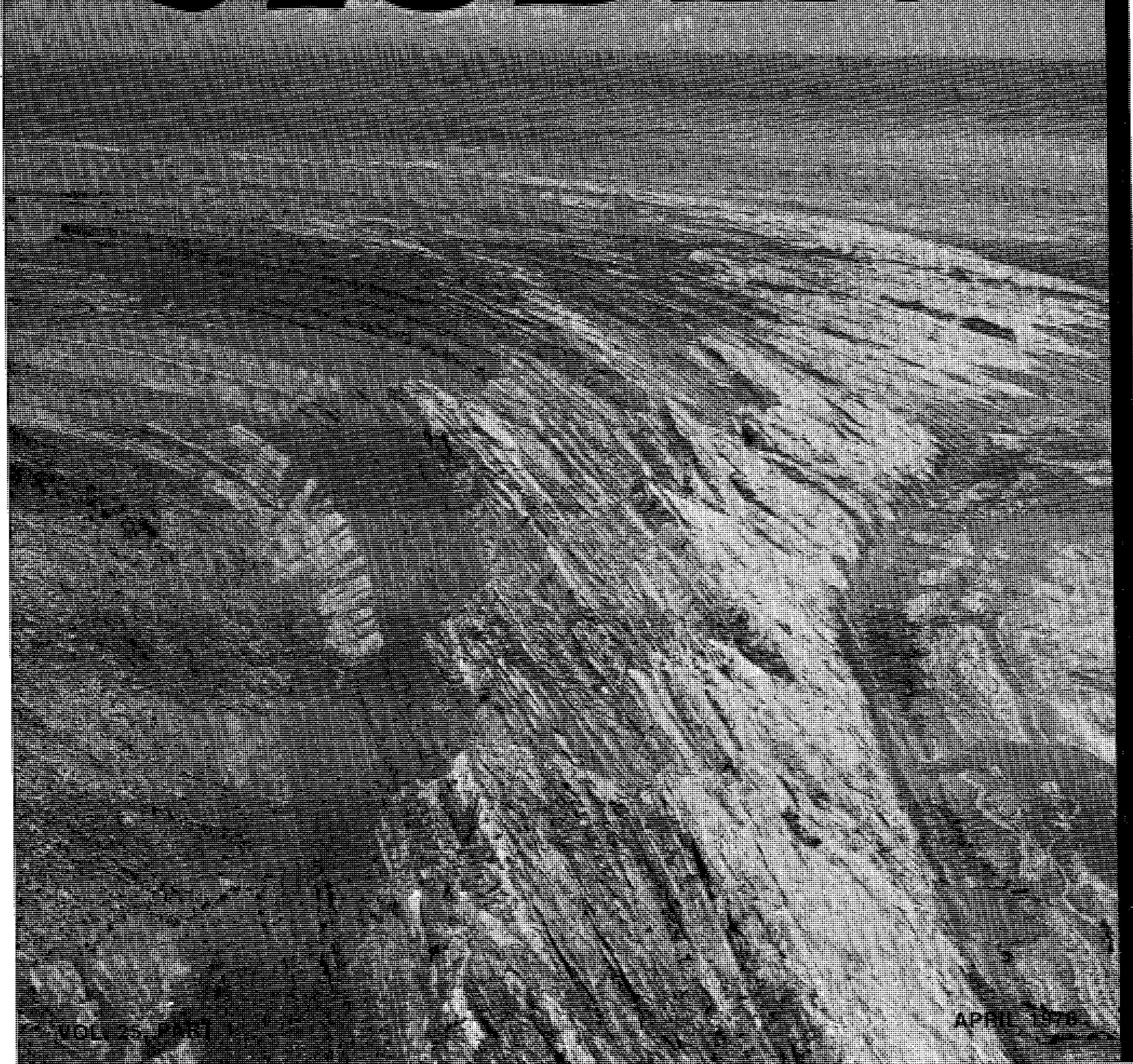

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THE GLORY OF GOD IS INTELLIGENCE

Cover: East flank of San Rafael Swell, Emery County, Utah; looking north. Photo by W. K. Hamblin.

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Geology of the Marysvale Volcanic Field, West Central Utah

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ABSTRACT.– The Cenozoic geologic history of the Marysvale area of west central Utah is largely a chronicle of volcanic events that took place during a succession of tectonic regimes. Volcanism began in late Oligocene time, about 30 m.y. ago, during a period of tectonic quiet. In the succeeding 10 m.y., a complex cluster of intermediate-composition volcanoes, surrounded by coalescing volcaniclastic aprons, and local ash-flow tuffs from caldera sources formed in an area 80–100 km across, in the southwestern High Plateaus; concurrently a widespread field of ash-flow tuffs developed in adjacent parts of the Great Basin to the west. Structural differentiation of the High Plateaus and the Great Basin probably began during this 10-m.y. span, but no extensive basin-range faulting took place until after it was over.

About 21–20 m.y. ago, composition of erupted rocks shifted abruptly from a predominantly intermediate constitution to highly silicic alkalic rhyolites. The largest volumes of rhyolites were erupted 21–17 m.y. ago from sources in the Tushar Mountains and the Antelope Range near Marysvale, where ash-flow tuffs and lava flows of the Mount Belknap Volcanics accumulated, and the major Mount Belknap and minor Red Hills calderas formed (Steven et al. 1977, Cunningham and Steven 1977).

Basin-range faulting began shortly after the Mount Belknap eruptions and continued through the remainder of Cenozoic time. Fluviatile and lacustrine sediments of the Miocene to Pleistocene Sevier River Formation (Callaghan 1938) were deposited in the developing structural basins; widespread but generally sparse basalt lava flows were interbedded in these sediments. Silicic alkalic rhyolite flows and domes were erupted elsewhere in western Utah during this same period, and together with the basalts define a bimodal compositional suite that is part of a regional assemblage of similar rocks erupted throughout western U.S. concurrently with late Cenozoic basin-range extensional faulting (Christiansen and Lipman 1972).

Mineralization took place episodically at one place or another in the Marysvale area from early Miocene (22 m.y. ago) until Pleistocene time (Kerr et al. 1957, Kerr 1968, Bassett et al. 1963, Callaghan 1973, Steven et al. 1977).

PREVOLCANIC ROCKS

The Marysvale volcanic field (fig. 1) extends across a major structural boundary that separates folded and faulted Paleozoic and Mesozoic sedimentary rocks of the late Mesozoic Sevier orogenic belt (Armstrong 1968) on the west from flat-lying strata of comparable age in the Colorado Plateaus province to the east. This transition zone was highly broken during later basin-range block faulting when the High Plateaus were developed, but the position of the Marysvale field above the earlier tectonic boundary is clear cut. Deep erosion took place after the Sevier orogeny, and the continental Claron Formation of Eocene and Oligocene age was deposited widely across the beveled edges of earlier deformed strata. The top of the Claron Formation provided a widespread surface of low relief across which the first Tertiary volcanic rocks accumulated (Mackin 1960).

A few hills of older sedimentary rocks protruded through the cover of Claron sedimentary rocks and formed local barriers that affected the distribution of the early volcanic units. One of these hills is now represented by an anticline of Paleozoic and Mesozoic rocks exposed in cross section on the face of Deer Trail Mountain on the east side of the Tushar Mountains 5–10 km south of Marysvale.

INTERMEDIATE-COMPOSITION VOLCANIC ROCKS OF LATE OLIGOCENE–EARLY MIOCENE AGE

Volcanism began in the Marysvale volcanic field about 30 m.y. ago when a few widely scattered andesitic to rhyodacitic volcanoes began to form. The best documented of these early volcanoes are in the Pavant Range in the northern part of the field where Caskey and Shuey (1975) and Steven et al. (1977) have described local accumulations of dark lavas and breccias. Anderson and Rowley (1975, p. 14) noted thin local deposits of ash-flow tuff, lava flows, volcanic breccia, and volcanic arenite of late Oligocene age at the base of their volcanic section along the southern margin of the field in the Black Mountains and northern Markagunt Plateau. A laccolithic(?) intrusion marking a volcanic center of this age was emplaced near the abandoned small community of Spry, 25 km north of Panguitch (Anderson and Rowley 1975, p. 16). An east–northeasterly line of volcanoes extending from the west side of the Tushar Mountains, through the Marysvale Canyon area, to the northern Sevier Plateau east of Monroe may have begun to form at this time.

These early accumulations in the Marysvale field were largely overwhelmed by tremendous outpourings of crystal-rich ash flows of the Needles Range Formation (Mackin 1960, Shuey et al. 1976) about 29 m.y. ago. The Needles Range Formation consists of at least three members of closely similar lithology derived from sources somewhere in the southeastern Great Basin to the west; these members covered more than 50,000 km². Over most of their extent in southwestern Utah and eastern Nevada, the Needles Range ash flows spread across a surface of low relief on older sedimentary rocks. In the Marysvale area, however, the Needles Range ash flows overlapped and locally abutted and wedged out against preexisting hills of sedimentary rocks (Deer Trail Mountain) or of somewhat older middle Tertiary volcanoes (Pavant Range, Spry area, Marysvale Canyon?). Along the northwest side of the Pavant Range, the Needles Range ash flows were contemporaneous with eruptions at local intermediate-composition volcanoes, and here the regional Needles Range ash-flow tuffs are complexly interlayered with locally derived lava flows and volcanic breccia. Where the local barriers did not exist, however, the Needles Range ash flows extended unbroken across the site of the later Marysvale volcanic field and, together with the underlying sedimentary Claron Formation, demonstrate that no topographic barrier existed along the trend of the transition zone between the present Great Basin and Colorado Plateaus provinces.

The local volcanic activity in the Marysvale volcanic field, which began before and continued during accumulation of the Needles Range Formation, became more widespread thereafter and formed a composite volcanic edifice consisting of stratovolcanoes with coalescing volcaniclastic aprons, shield volcanoes, and plateaus of flat-lying lava flows and welded ash-flow tuffs. An east-northeast-trending line of stratovolcanoes extended across the north central part of the field north of Marysvale from the west side of the Tushar Mountains, 15 km north of Beaver, through the Kimberly area, Deer Creek Canyon, Marysvale Canyon, Antelope Range, to the northern Sevier Plateau east of Monroe. Farther south, Anderson and Rowley (1975) reported scattered vent-facies volcanic rocks (mostly lava flows and flow breccia) extending along an east-trending lineament (Rowley, Lipman et al. 1978) from the northern Black Mountains across the southern Tushar Mountains and northern Markagunt Plateau. These stratovolcanoes were flanked in part by thick aprons of volcaniclastic debris (mostly volcanic mudflow breccia) that are especially prominent along the south side of the east-northeast-alined volcanoes north of Marysvale and around the scattered volcanic centers farther south. Volcaniclastic debris is curiously nearly absent along the north flank of the stratovolcanoes north of Marysvale, as will be discussed later.

A major shield volcano of basaltic andesite formed along the north flank of the east-northeast-trending volcanoes from the eastern flank of the Pavant Range eastward across the northern Sevier Plateau. This shield is at least 700 m thick near its center (Callaghan and Parker 1961a, 1962b), and it intertongues westward into a volcanic plateau consisting of flat-lying flows and low domes of rhyodacite and quartz latite lava and a thick accumulation of crystal-rich ash-flow tuff of the Oligocene Three Creeks Tuff Member of the Bullion Canyon Volcanics. The source of the Three Creeks Tuff Member is in the Clear Creek drainage area of the southern Pavant Range, where it is marked by an obscure trapdoor-type subsided block, or cauldron (Steven et al. 1977).

The shield volcano and volcanic plateau along the north side of the east-northeast-trending line of volcanoes were partly responsible for excluding volcaniclastic deposits from this flank of the volcanic field, but other factors also may have been involved. In the eastern Pavant Range west of Elsinore and near the present edge of the volcanic rocks, the Needles Range Formation near the base of the volcanic section is separated by only 15–20 m of dark lava flows from a higher welded ash-flow-tuff unit possibly correlative with the Osiris Tuff. Farther south in the Marysvale Canyon area, neither the base of the volcanic section nor the Needles Range Formation is exposed, but overlying vent-facies volcanic rocks at least 400–500 m thick are exposed beneath the possible Osiris equivalent. This southward increase in volume and thickness of vent-facies rocks seems to require southward tilting of this part of the volcanic field concurrent with eruptions and prior to emplacement of the Osiris(?) Tuff; and such tilting could also have inhibited accumulation of volcaniclastic debris along the northern side of the alined stratovolcanoes.

In the northern Sevier Plateau south of the east-northeast-trending volcanoes, the volcanic edifice is largely a plateau consisting of flat-lying intermediate-composition lava flows with some interlayered volcanic mudflow breccia and welded ash-flow tuff sheets. The Needles Range Formation is exposed locally at the base of the cliffs along the west side of the plateau, so nearly the full section of remaining volcanic rocks, about 1 km thick, is exposed. Farther south toward Kingston Canyon, alluvial-facies rocks become increasingly abundant. They predominate in the southern Sevier Plateau south of Kingston Canyon, where only sparse local lava flows and two distinctive ash-flow tuff units, the Oligocene and Miocene Kingston Canyon and Miocene Antimony Tuff members of the Mount Dutton Formation, are present (Rowley and Anderson 1975).

Volcanic mudflow breccia predominates in the central to southern Tushar Mountains south of the east-northeast-trending line of volcanoes, but vent-facies volcanics are locally prominent near former volcanic centers. Two major ash-flow tuff sheets are well exposed in the central Tushar Mountains; the lower is the Three Creeks Tuff Member already mentioned, and the other is the Delano Peak Tuff Member (Miocene) of the Bullion Canyon Volcanics, which came from a cauldron source 7 km across that occupies much of the central Tushar Mountains north of Beaver River.

South of the Beaver River, in the southernmost Tushar Mountains and northernmost Markagunt Plateau, the volcanic pile consists largely of local vent-facies accumulations at volcanic centers formed along an east-trending lineament (Rowley, Lipman et al. 1978). Some locally distinct units of Miocene age have been recognized and mapped (Anderson and Rowley 1975) in the northern Markagunt Plateau. Chief among these are the autoclastic and mudflow breccia of the Buckskin Breccia derived from the Spry igneous center; the cross-bedded dune sand of the Bear Valley Formation caught against the Spry volcanic pile and filling grabens; and plugs, lava flows, and volcanic mudflow breccia of the Horse Valley Formation in the Black Mountains. The Osiris Tuff is a distinctive sheet of ash-flow tuff that is distributed widely

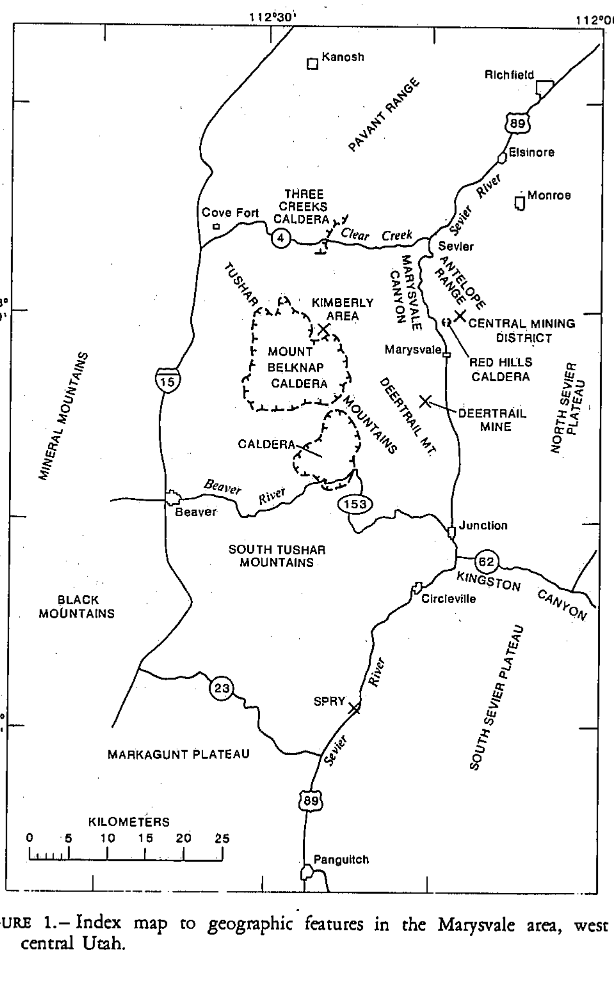

FIGURE 1.– Index map to geographic features in the Marysvale area, west central Utah.

throughout the eastern part of the Marysvale volcanic field. It is near the top of the volcanic succession in most places and provides a convenient marker bed. The source of the Osiris Tuff is probably in the northern Sevier Plateau east of Marysvale (P. L. Williams pers. commun. 1970).

The detailed stratigraphy of many parts of the complex pile of generally intermediate-composition volcanic rocks of late Oligocene–early Miocene age has been worked out only in part, and many important relations remain to be established. The whole succession in the northern part of the field was included at one place or another in the Bullion Canyon Volcanics by Callaghan (1938, 1939), Callaghan and Parker (1961a, 1961b, 1962a, 1962b), and Willard and Callaghan (1962); but in other places the succession was broken up into several units of which the Bullion Canyon was only one. Most rocks on the southern flank of the volcanic field belong to the Mount Dutton Formation of Anderson and Rowley (1975). Presently available data are insufficient to make meaningful lateral correlations between units within these two broadly equivalent assemblages of rocks.

Marginally to the south and southwest, the locally derived intermediate-composition rocks of the Marysvale volcanic field intertongue with regional ash-flow tuffs in the southeastern Great Basin (Mackin 1960; Williams 1960, 1967; Anderson and Rowley 1975). The densely welded and fluidal-textured silicic ash-flow tuff and lava flows of the Isom Formation (26–25 m.y.) underlie alluvial facies of the Mount Dutton Formation, but the position of the Isom relative to older intermediate-composition rocks in the northern part of the field is not known. Younger ash-flow tuff formations of the Quichapa Group (24–20 m.y.) are interlayered marginally at higher levels and also are not present in the northern part of the field. Interestingly, none of these welded tuff sheets of Great Basin provenance extends significantly east of the line of the present-day Hurricane Cliffs, which now mark the boundary between the Great Basin and the High Plateaus. The ash-flow tuffs may have been excluded in part by the contemporaneous volcanic rocks in the Marysvale field or by structural disturbances along this line which may have marked the beginning of differentiation between what are now distinctly different geologic provinces.

MOUNT BELKNAP VOLCANICS

About 21 m.y. ago the compositions of volcanic rocks erupted in the Marysvale volcanic field changed drastically and abruptly from predominantly intermediate compositions to silicic alkalic rhyolite. This change broadly coincided with the beginning of extensional basin-range tectonics in adjacent parts of the Great Basin, and the rocks are interpreted to belong to the bimodal basalt-rhyolite assemblage that was erupted widely throughout the Basin-Range province of western U.S. in later Cenozoic time (Christiansen and Lipman 1972).

The most voluminous rhyolites in the Marysvale field were erupted shortly after the compositional changeover, during the period 21–17 m.y. ago, and they constitute a composite unit that has been redefined (Steven et al. 1977) as the Mount Belknap Volcanics. The Mount Belknap Volcanics were erupted from two contemporaneously active source areas, and the products from the two sources intermix complexly (Cunningham and Steven 1977). The eastern source area is largely in the southern part of the Antelope Range, but it extends into the lower foothills of the Tushar Mountains to the west. Eruptions began 21–20 m.y. ago in the eastern part of the source area, where a series of volcanic domes was erupted in an area about 5 km across. Volcanic activity progressed west-southwestward with the emplacement of a stock of fine-grained granite on the western flank of the Antelope Range about 19 m.y. ago, the nearby eruption of ash-flow tuffs of the Red Hills Member of the Mount Belknap Volcanics, and related subsidence of the small Red Hills caldera (1 km diameter) about 18 m.y. ago. Final eruptions took place 18–17 m.y. ago in the Gray Hills (name of Kerr et al. 1957, pl. 12) in the southwestern part of the eastern source area, where many viscous rhyolite lava flows and volcanic domes accumulated above their source vents.

The western source area is marked by the major Mount Belknap caldera, 11 km across, which was the source of voluminous rhyolite ash flows and local lava flows 19–18 m.y. ago. Outflow ash-flow tuffs formed the Joe Lott Tuff Member of the Mount Belknap Volcanics; eruption of this member resulted in subsidence of the Mount Belknap caldera, which in turn was filled with an alternating sequence of ash-flow tuffs similar to those in the Joe Lott and by rhyolite lava flows of identical chemistry. The outflow Joe Lott tuffs intertongue with varied products from the eastern source area along the lower slopes of the Tushar Mountains between the two source areas.

The source areas of the Mount Belknap Volcanics were in the eroded near-source lavas and breccia of earlier intermediate-composition stratovolcanoes. The outflow rocks accumulated in valleys extending radially out from the elevated cores of these older volcanoes and in low areas on the marginal volcaniclastic aprons and volcanic plateaus. To the south, the Joe Lott Tuff Member filled the older caldera source of the Delano Peak Tuff Member of the Bullion Canyon Volcanics.

The evolution of the Red Hills and Mount Belknap calderas has been interpreted in relation to the eruptive history of the Mount Belknap Volcanics by Cunningham and Steven (1977). They believed that the source areas developed above cupolas extending upward from a common magma chamber, and that the differences in eruptive behavior at the two sources reflected differences in size, shape, and depth of the two cupolas.

SEVIER RIVER FORMATION AND BIMODAL BASALT RHYOLITE VOLCANISM

Basin-range faulting became active in the High Plateaus area in middle Miocene time and was particularly intense during later Miocene and Pliocene time. Recent low scarps cutting Quaternary alluvial deposits have been recognized widely, particularly in the Cove Fort, Beaver, and Marysvale areas, and attest to continued activity, but possibly at a reduced rate, to the present.

Fluviatile and lacustrine sediments of the Sevier River Formation were deposited in the developing structural basins during Miocene through early Pleistocene time (Callaghan 1938). The character of the sediment ranges widely from basin to basin, depending on local source rocks, configuration of the basin, and many other factors. Exposures range from loose deposits of sand and gravel to well-bedded, tan-to-salmon-colored, compacted, ashy siltstones and sandstones. White ash beds are common, particularly in more evenly bedded local sequences. An ash bed near the base of the Sevier River Formation on the north side of the Tushar Mountains yielded a zircon fission-track age of about 14 m.y., whereas another ash bed near the top of the succession at Sevier yielded a zircon fission track age of about 7 m.y. (Steven et al. 1977). The ages are not of the oldest or the youngest strata in the Sevier River Formation, but they do give some idea of the general span of sedimentation. Modern alluvial valley fills locally lie unconformably on deformed Sevier River Formation strata.

Mafic volcanic eruptions took place widely during Sevier River sedimentation, and basalt flows are interlayered with the fluviatile sedimentary rocks of the formation at many places. These flows range in age from middle Miocene to Pleistocene or even Holocene, and near Cove Fort and the southern Markagunt Plateau some basalt shields and cinder cones are virtually unmodified by erosion.

Alkalic rhyolite was erupted from scattered centers during the same late Cenozoic interval (Mehnert et al. 1978), but generally in quite small volume. Rhyolite centers erupted 20–7 m.y. ago are sparsely distributed along an east-west zone of igneous centers and structural disturbances that Rowley, Lipman et al. (1978) have called the Blue Ribbon lineament. Several small rhyolite flows and plugs at and near Phonolite Mountain in Kingston Canyon are examples. Small rhyolite domes, flows, and ash-flow tuffs were erupted in the Mineral Range as recently as 0.8–0.5 m.y. (Lipman et al. 1975); they are in close proximity to potential geothermal steam fields.

MINERALIZATION

Mineralization took place at many times in the Marysvale volcanic field, beginning about 22 m.y. ago and extending into the Pleistocene(?) or Holocene (Steven et al. 1977). The oldest mineralization was associated with emplacement of 23-m.y.-old quartz monzonitic intrusions into the cores of older intermediate composition volcanoes. The gold–silver deposits in the Kimberly area and the alunite–kaolinite deposits in the southern Antelope Range are examples. Uranium was deposited widely in the core of the Mount Belknap caldera some time after it was filled by ash-flow tuffs and lava flows about 18 m.y. ago. A mineralized area in the eastern Tushar Mountains is zoned around an intensely altered core on Alunite Ridge. It has base- and precious-metal deposits in veins and mantos on its northern and eastern periphery. K/Ar ages in sericite and alunite from this mineralized area indicate that mineralization took place 14–13 m.y. ago. The productive uranium deposits in the Central Mining district in the southern Antelope Range perhaps formed between 13 and 9 m.y. ago. Alunite deposits on the west side of the Tushar Mountains 13 km north of Beaver have been dated (K/Ar on alunite) as 9 m.y. old. Native sulfur deposits at Sulphurdale and Sulphur Peak near Cove Fort are in alluvial fan deposits near Holocene fault scarps. Mineralization seems to have been related to nearby basaltic volcanoes of Pleistocene or Holocene age.

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