

# GEOLOGIC MAP OF THE TONOPAH 1° BY 2° QUADRANGLE, CENTRAL NEVADA

By

Donald H. Whitebread and David A. John

## INTRODUCTION

This map is part of a folio of maps of the Tonopah 1° by 2° quadrangle, Nevada, prepared under the Conterminous United States Mineral Assessment Program.

## DESCRIPTION OF MAP UNITS

### SURFICIAL DEPOSITS

- Qa Alluvial, lacustrine, and eolian deposits (Quaternary)**—As mapped, locally includes Tertiary gravel
- QTls Landslide deposits (Quaternary and Tertiary)**

### SEDIMENTARY ROCKS AND UNCONSOLIDATED DEPOSITS

- Ts<sub>4</sub> Sedimentary rocks and bedded tuff (Tertiary)**—Tuffaceous siltstone and sandstone, bedded tuff, and diatomite. Includes Esmeralda and Siebert Formations. K-Ar ages about 11-13 Ma (Evernden and James, 1964; Evernden and others, 1964) for Esmeralda Formation and 13-17 Ma (Bonham and Garside, 1979) for Siebert Formation
- Ts<sub>3</sub> Sedimentary rocks and bedded tuff (Tertiary)**—Sandstone and siltstone, commonly tuffaceous. Some interbeds and lenses of conglomerate and minor tuff
- Ts<sub>2</sub> Sedimentary rocks and bedded tuff (Tertiary)**—Tuffaceous siltstone and sandstone, limestone, minor conglomerate, and bedded tuff. Includes Gilmore Gulch Formation
- Ts<sub>1</sub> Sedimentary rocks and bedded tuff (Tertiary)**—Tuffaceous siltstone and sandstone, conglomerate, limestone, and bedded tuff

**LAVA FLOWS AND SHALLOW INTRUSIVE ROCKS**  
[K-Ar ages published before 1977 are corrected using the constants recommended by IUGS Subcommission on Geochronology (Dalrymple, 1979)]

- Qb Basalt of Lunar Crater area (Quaternary)**—Lava flows and local cinders and dikes
- Tba Basalt and andesite flows (Tertiary)**—As mapped, probably includes some Quaternary lava flows in Pancake Range. Includes trachyandesite of Red Mountain and trachyandesite of Thunder Mountain in San Antonio Mountains
- Tr<sub>4</sub> Rhyolitic rocks (Tertiary)**—Rhyolitic to dacitic flows, dikes, and small intrusive bodies. Includes Brougher Rhyolite of Bonham and Garside (1979) and Oddie Rhyolite
- Ta<sub>4</sub> Andesitic rocks (Tertiary)**—Andesitic to latitic flows, volcanic breccia, and dikes. Includes Gilbert Andesite, Mizpah Trachyte, and volcanics of Lime Mountain of Bonham and Garside (1979)
- Ta<sub>3</sub> Andesitic rocks (Tertiary)**—Andesitic to latitic flows, flow breccias, sills, dikes, and plugs
- Tr<sub>3</sub> Rhyolitic rocks (Tertiary)**—Rhyolitic to dacitic flows, dikes, sills, and irregular small intrusive bodies
- Ta<sub>2</sub> Andesitic rocks (Tertiary)**—Andesitic to latitic flows, flow breccias, dikes, sills, and minor intrusive bodies
- Tr<sub>2</sub> Rhyolitic rocks (Tertiary)**—Rhyolitic to dacitic flows and small intrusive bodies. Commonly flow banded. Includes some rhyolitic tuff in Shoshone Mountains
- Ta<sub>1</sub> Andesitic rocks (Tertiary)**—Andesitic to latitic flows. Locally, includes some bedded tuff and tuffaceous sedimentary rocks
- Tr<sub>1</sub> Rhyolitic rocks (Tertiary)**—Rhyolitic, quartz latitic, and rhyodacitic lava flows, locally flow banded, and rhyolitic dikes. Includes some tuffaceous sedimentary rocks and bedded tuff

# ASH-FLOW TUFFS

[K-Ar ages published before 1977 are corrected using the constants recommended by IUGS Subcommission on Geochronology (Dalrymple, 1979)]

## Area 1

- Tt<sub>4</sub>** Ash-flow tuff (Tertiary)—Pumice-rich and lithic-rich tuff. Locally, includes sedimentary rocks
- Tf** Fraction Tuff (Tertiary)—Nonwelded to densely welded, crystal-poor, locally lithic-rich quartz latitic to rhyolitic ash-flow tuff
- Tt<sub>3</sub>** Ash-flow tuff (Tertiary)—Crystal-rich to crystal-poor rhyolitic ash-flow tuff. Includes tuffs of Goldyke and Sheep Canyon in Paradise Range
- Ttt** Tuff of Toiyabe (Tertiary)—Densely welded, crystal-rich quartz latitic to rhyolitic welded tuff. Equivalent in part to the now-abandoned Toiyabe Quartz Latite as mapped by Ferguson and Cathcart (1954) and Kleinhampl and Ziony (1985) (see John, 1992)
- Tt<sub>2</sub>** Ash-flow tuff (Tertiary)—Rhyolitic to rhyodacitic ash-flow tuff. Includes some tuffaceous sedimentary rocks and rhyolitic flows. In western part of quadrangle includes tuffs of Gabbs Valley, Davis Mine, Pactolus, Crow Springs, Castle Peak, and Summit Spring and Mission Spring Formation of Vitaliano and Vitaliano (1972). In Toiyabe Range includes tuffs of Cloverdale, Rainier Mountain, North Fork, and Mahogany Mountain
- Tad** Tuff of Arc Dome (Tertiary)—Gray to pale-red, densely welded, crystal-rich rhyolitic ash-flow tuff. Contains conspicuous smoky quartz phenocrysts
- Tpc** Tuff of Peavine Creek (Tertiary)—Buff to light-brown, nonwelded to densely welded, crystal-poor rhyolitic ash-flow and ash-fall tuff
- Trr** Round Rock Formation (Tertiary)—Crystal-poor, latitic, quartz latitic, and rhyolitic lithic-rich ash-flow and ash-fall tuff. Subordinate interbedded sandstone
- Tt<sub>1</sub>** Ash-flow tuff (Tertiary)—Rhyolitic ash-flow tuff and lava flows. Age distinction from younger tuff units based on more strongly altered character. Consists of tuffs of Davis mine and Pactolus in Paradise Range and Mission Spring Formation of Vitaliano and Vitaliano (1972) in Shoshone Mountains
- TMzd** Darrough Felsite (Tertiary and Mesozoic)—Locally silicified, crystal-rich to lithic-rich rhyolitic to quartz latitic or rhyodacitic ash-flow tuff

and volcanoclastic sedimentary rocks. Most of Darrough Felsite is Cretaceous and (or) older in age as described by Brem and others (1991), but in the area of this report, unit is considered to consist of rocks of both Mesozoic and Tertiary age (G.F. Brem, written commun., 1986)

- Mzt** Ash-flow tuff (Mesozoic)—Dacitic and rhyodacitic ash-flow tuff and minor sandstone and conglomerate

## Area 2

- Tbm** Bates Mountain Tuff (Tertiary)—Grayish- to pinkish-orange, moderately welded, crystal-poor rhyolitic ash-flow tuff
- Tt<sub>2</sub>** Ash-flow tuff (Tertiary)—Rhyolitic to rhyodacitic ash-flow tuff. Includes tuffs of Meadow Canyon, Trail Canyon, and Ryecroft Canyon
- Tpc** Tuff of Peavine Creek (Tertiary)—Buff to light-brown, nonwelded to densely welded, crystal-poor rhyolitic ash-flow and ash-fall tuff
- Trr** Round Rock Formation (Tertiary)—Crystal-poor, latitic, quartz latitic, and rhyolitic, lithic-rich, ash-flow and ash-fall tuff and subordinate interbedded sandstone
- Tmj** Tuff of Mount Jefferson (Tertiary)—Reddish-brown, poorly to densely welded, moderately crystal-rich, rhyolitic to rhyodacitic ash-flow tuff

## Area 3

- Tsw** Tuff of Saulsbury Wash (Miocene)—Reddish-brown to purple, crystal-rich rhyolitic welded ash-flow tuff
- Tt<sub>2</sub>** Ash-flow tuff (Tertiary)—Rhyolitic to rhyodacitic ash-flow tuff. Includes some tuffaceous sedimentary rocks and rhyolitic flows. Includes tuffs of Black Beauty Mesa, Buckwheat Rim, Buckskin Point, Lunar Cuesta, Orange Lichen Creek, Pott Hole Valley, Crested Wheat Ridge, Moores Station Buttes, The Needles, Palisade Mesa, and Halligan Mesa
- Tsp** Shingle Pass Tuff (Tertiary)—Reddish-gray, pale-red, dark-red, and pale-red purple, nonwelded to densely welded crystal-poor rhyolitic ash-flow tuff
- Tkc** Tuff of Kiln Canyon (Tertiary)—Light-gray to grayish-orange to dark-reddish-brown, nonwelded to densely welded, locally lithic-rich, pumiceous, crystal-rich rhyolitic to quartz latitic ash-flow tuff
- Tbt** Tuff of Big Ten Peak (Tertiary)—Light-gray to buff to orange, lithic-rich

rhyolitic ash-flow tuff. Locally includes air-fall tuff and laucustrine sedimentary rocks

#### Area 4

- Tbm Bates Mountain Tuff (Tertiary)**—Grayish- to pinkish-orange, moderately welded, crystal-poor rhyolitic ash-flow tuff
- Tgw Granite-weathering tuff (Tertiary)**—Reddish-gray and reddish-brown, partially to densely welded, crystal-rich rhyolitic welded tuff
- Tt<sub>2</sub> Ash-flow tuff (Tertiary)**—Rhyolitic to rhyodacitic ash-flow tuff. Includes some tuffaceous sedimentary rocks and rhyolitic flows. Includes tuffs of Black Beauty Mesa, Buckwheat Rim, Buckskin Point, Lunar Cuesta, Orange Lichen Creek, Pott Hole Valley, Crested Wheat Ridge, Moores Station Buttes, The Needles, Palisade Mesa, and Halligan Mesa
- Tsp Shingle Pass Tuff (Tertiary)**—Reddish-gray, pale-red, dark-red, and pale-red purple, nonwelded to densely welded crystal-poor rhyolitic ash-flow tuff
- Tkc Tuff of Kiln Canyon (Tertiary)**—Light-gray to grayish-orange to dark-reddish-brown, nonwelded to densely welded, locally lithic-rich, pumiceous, crystal-rich rhyolitic to quartz latitic ash-flow tuff
- Tm Monotony Tuff (Tertiary)**—Purplish-gray to brown, partially to densely welded, crystal-rich rhyodacitic and quartz latitic ash-flow tuff containing conspicuous biotite and quartz phenocrysts
- Thc Tuff of Hot Creek Canyon (Tertiary)**—Light-gray to grayish-purple, partially to densely, crystal-rich quartz latitic and rhyolitic ash-flow tuff containing prominent quartz phenocrysts
- Twm Tuff of Williams Ridge and Morey Peak (Tertiary)**—Gray to dusky purple, partially to densely welded, crystal-rich rhyodacitic and quartz latitic welded tuff that contains prominent phenocrysts of biotite and quartz
- Twb Windous Butte Formation (Tertiary)**—Brownish-gray to pale-brown, moderately to densely welded, crystal-rich quartz latitic to rhyolitic ash-flow tuff
- Tsc Stone Cabin Formation (Tertiary)**—Light-gray to pinkish-gray, locally lithic-rich, crystal-rich rhyolitic ash-flow tuff

#### PLUTONIC AND INTRUSIVE ROCKS [Plutonic rock names based on IUGS modal classification (Streckeisen, 1976)]

- TMzg Granitic rocks (Tertiary or Mesozoic)**—Granite, granodiorite, granodiorite porphyry, and quartz diorite
- TKg Granitic rocks (Tertiary or Cretaceous)**—Mostly fine-grained granodiorite
- Tg Granitic rocks (Tertiary)**—Granite, granodiorite, and quartz diorite. Unit includes dike swarm near Round Mountain
- Mzd Dioritic rocks (Mesozoic)**—Mostly diorite and quartz diorite. Field relations do not permit age assignment other than Mesozoic
- Mzg Granitic rocks (Mesozoic)**—Granite, granodiorite, quartz monzonite, quartz monzodiorite, and quartz diorite. Field relations do not permit age assignment other than Mesozoic, but most plutons presumably are of Late Cretaceous age
- Kd Dioritic rocks (Cretaceous)**—Diorite and gabbro. Ages determined isotopically or by field relations with rocks whose ages have been determined isotopically
- Kg Granitic rocks (Cretaceous)**—Mostly granite, granodiorite, quartz monzonite, and quartz monzodiorite. Ages determined isotopically or by field relations with rocks whose ages have been determined isotopically
- JFg Granitic rocks (Jurassic or Triassic)**—Granodiorite to quartz monzodiorite of Crow Springs pluton
- Jg Granitic rocks (Jurassic)**—Granite and granodiorite
- Tg Granitic rocks (Triassic)**—Granodiorite to quartz monzodiorite of Fraziers Well pluton

#### SEDIMENTARY AND VOLCANIC ROCKS

##### Area 1

- Jd Dunlap Formation and lithologically equivalent rocks (Middle? and Early Jurassic)**—Breccia, conglomerate, sandstone, volcanoclastic sedimentary rocks, limestone, dolomite, andesitic flows, and pyroclastic rocks. Dunlap Formation is considered to be Early and Middle(?) Jurassic in age on basis of fossil evidence (Oldow and Bartel, 1987; Silberling, 1984)
- JFv Volcano Peak Group of Taylor and others (1983) (Jurassic and Triassic)**—Limestone, siltstone, and

argillite. Consists of Sunrise and Gabbs Formations of Taylor and others (1983)

**MzPg Greenstone (Mesozoic or Paleozoic)**—Includes some volcanoclastic rocks and limestone

**Fl Luning Formation and lithologically equivalent rocks (Triassic)**—Limestone, dolomite, shale, sandstone, and conglomerate. As mapped may locally include some rocks of Permian age

**Tgv Grantsville Formation (Triassic)**—Conglomerate, argillite, and limestone

**Tc Candelaria Formation (Triassic)**—Argillite, siltstone, quartzite, conglomerate, and limestone. Volcanogenic debris in upper part

**Pm Mina Formation of Speed (1977) (Permian)**—Volcanoclastic argillite and quartzite, and chert

**Pd Diablo Formation (Permian)**—Conglomerate, quartzite, argillite, chert, and limestone. As mapped, locally includes clastic rocks of Pennsylvanian age

**PMh Havallah sequence of Silberling and Roberts (1962) (Permian, Pennsylvanian, and Mississippian)**—Argillite, chert, greenstone, and minor sandstone, conglomerate, and limestone

**Mp Pablo Formation (Mississippian)**—Argillite, chert, greenstone, and minor quartzite and conglomerate

**Mc Carbonate rocks (Mississippian)**—Dolomite, limestone, and minor shale

**DEsv Sedimentary and volcanic rocks (Devonian to Cambrian)**—Mainly argillite, chert, and greenstone. Consists of Palmetto Formation, Valmy(?) Formation, Pinecone Formation of Kay and Crawford (1964), and unnamed rocks in southern Toquima Range

**DOc Carbonate rocks (Devonian, Silurian, and Ordovician)**—Consists of Ely Springs Dolomite, Hanson Creek Formation, Roberts Mountains Formation, and Lone Mountain Dolomite, and Gatecliff Formation, Diana Limestone, and Masket Shale of Kay and Crawford (1964)

**OEs Schist, argillite, shale, limestone, and quartzite (Ordovician and Cambrian?)**—Consists Mayflower Schist, Zanzibar Limestone, and Toquima Formation, and rocks of early Paleozoic(?) age in Paradise Range and Shoshone Mountains

## Area 2

**MzPzs Serpentinite (Mesozoic or Paleozoic)**—Tectonically interleaved with Paleozoic oceanic sedimentary and mafic volcanic rocks

**Tpcd Candelaria Formation (Triassic) and Diablo Formation (Permian), undivided**

**PMh Havallah sequence of Silberling and Roberts (1962) (Permian, Pennsylvanian, and Mississippian)**—Argillite, chert, greenstone, and minor sandstone, conglomerate, and limestone

**IPwp Wildcat Peak Formation (Pennsylvanian)**—Limestone, sandy limestone, and chert- and limestone-pebble conglomerate

**DEsv Sedimentary and volcanic rocks (Devonian to Cambrian)**—Mainly argillite, chert, and greenstone. Consists of Palmetto Formation, Valmy(?) Formation, Pinecone Formation of Kay and Crawford (1964), and unnamed rocks in southern Toquima Range

**DOc Carbonate rocks (Devonian, Silurian, and Ordovician)**—Consists of Ely Springs Dolomite, Hanson Creek Formation, Roberts Mountains Formation, and Lone Mountain Dolomite, and Gatecliff Formation, Diana Limestone, and Masket Shale of Kay and Crawford (1964)

**OEs Schist, argillite, shale, limestone, and quartzite (Ordovician and Cambrian?)**—Consists Mayflower Schist, Zanzibar Limestone, and Toquima Formation, and rocks of early Paleozoic(?) age in Paradise Range and Shoshone Mountains

**Oep Eureka Quartzite and Pogonip Group, undivided (Ordovician)**—Includes Perkins Canyon Formation of Kay and Crawford (1964)

**Eqs Quartzite, siltstone, schist, and limestone (Cambrian)**—Includes Harkless and Gold Hill Formations

**EZms Marble, dolomite, phyllite, siltstone, and quartzite (Cambrian and Late Proterozoic)**—Consists of Wyman Formation, Reed Dolomite, and Deep Spring Formation

## Area 3

**PMh Havallah sequence of Silberling and Roberts (1962) (Permian, Pennsylvanian, and Mississippian)**—Argillite, chert,

- greenstone, and minor sandstone, conglomerate, and limestone
- PPs Sedimentary rocks (Permian and Pennsylvanian)**—Mainly conglomerate, sandstone, or sedimentary breccia, but includes subordinate chert, siltstone, argillite, and limestone
- MDs Shale, limestone, sandstone, and conglomerate (Mississippian and Devonian)**—Consists of Pilot Shale, Joana Limestone, Eleana Formation, Chainman Shale, Diamond Peak Formation, and Tripon Pass Limestone
- Dc Carbonate rocks (Devonian)**—Consists of Devils Gate Limestone, Denay Limestone, and McColley Canyon Formation
- DOc Carbonate rocks (Devonian, Silurian, and Ordovician)**—Consists of Ely Springs Dolomite, Hanson Creek Formation, Roberts Mountains Formation, and Lone Mountain Dolomite, and Gatecliff Formation, Diana Limestone, and Masket Shale of Kay and Crawford (1964)
- OEs Schist, argillite, shale, limestone, and quartzite (Ordovician and Cambrian?)**—Consists Mayflower Schist, Zanzibar Limestone, and Toquima Formation, and rocks of early Paleozoic(?) age in Paradise Range and Shoshone Mountains
- Oep Eureka Quartzite and Pogonip Group, undivided (Ordovician)**—Includes Perkins Canyon Formation of Kay and Crawford (1964)
- Eqs Quartzite, siltstone, schist, and limestone (Cambrian)**—Includes Harkless and Gold Hill Formations

#### Area 4

- Ts Sedimentary rocks (Triassic)**—Siltstone, sandstone, conglomerate, and limestone
- PMh Havallah sequence of Silberling and Roberts (1962) (Permian, Pennsylvanian, and Mississippian)**—Argillite, chert, greenstone, and minor sandstone, conglomerate, and limestone
- PPs Sedimentary rocks (Permian and Pennsylvanian)**—Mainly conglomerate, sandstone, or sedimentary breccia, but includes subordinate chert, siltstone, argillite, and limestone
- MDs Shale, limestone, sandstone, and conglomerate (Mississippian and Devonian)**—Consists of Pilot Shale, Joana Limestone, Eleana

- Formation, Chainman Shale, Diamond Peak Formation, and Tripon Pass Limestone
- Dw Woodruff(?) Formation (Devonian)**—Siltstone, shale, chert, and minor sandstone. Consists of rocks previously mapped as Cockalorum Wash Formation by Kleinhampl and Ziony (1985)
- Dc Carbonate rocks (Devonian)**—Consists of Devils Gate Limestone, Denay Limestone, and McColley Canyon Formation
- DOc Carbonate rocks (Devonian, Silurian, and Ordovician)**—Consists of Ely Springs Dolomite, Hanson Creek Formation, Roberts Mountains Formation, and Lone Mountain Dolomite, and Gatecliff Formation, Diana Limestone, and Masket Shale of Kay and Crawford (1964)
- Oep Eureka Quartzite and Pogonip Group, undivided (Ordovician)**—Includes Perkins Canyon Formation of Kay and Crawford (1964)
- OEc Carbonate rocks (Ordovician and Cambrian)**—Consists of Hales Limestone, Windfall Formation, and lower part of Pogonip Group
- Els Limestone and shale (Cambrian)**—Includes Swarbrick Formation and Dunderberg Shale

#### REFERENCES CITED

- Armstrong, R.L., 1970, Geochronology of Tertiary igneous rocks, eastern Basin and Range Province, western Utah, eastern Nevada, and vicinity, U.S.A.: *Geochimica et Cosmochimica Acta*, v. 34, p. 203-232.
- Armstrong, R.L., Dick, Henry, and Vitaliano, C.J., 1972, K-Ar dates and strontium isotope initial ratios of some Cenozoic volcanic rocks from west-central Nevada: *Isochron/West*, no. 3, p. 23-28.
- Babaie, H.A., 1984, Structural and tectonic history of the Golconda allochthon, southern Toiyabe Range, Nevada: Evanston, Ill., Northwestern University, Ph.D. dissertation, 236 p.
- Boden, D.R., 1986, Eruptive history and structural development of the Toquima caldera complex, central Nevada: *Geological Society of America Bulletin*, v. 97, no. 1, p. 61-74.
- Bonham, H.F., Jr., and Garside, L.J., 1979, Geology of the Tonopah, Lone Mountain, Klondike, and northern Mud Lake quadrangles, Nevada: Nevada Bureau of Mines and Geology Bulletin 92, 142 p.
- Brem, G.F., John, D.A., Nash, J.T., Poole, F.G., and Snyder, D.B., 1991, Mineral resources of the Arc Dome Wilderness Recommendation

- Area, Nye County, Nevada: U.S. Geological Survey Bulletin 1961, 21 p.
- Dalrymple, G.B., 1979, Critical tables for conversion of K-Ar ages from old to new constants: *Geology*, v. 7, p. 558-560.
- Deino, A.L., 1989, Single-crystal  $^{40}\text{Ar}/^{39}\text{Ar}$  dating as an aide in correlation of ash flows: Examples from the Chimney Spring/New Pass Tuffs and the Nine Hill/Bates Mountain Tuffs of California and Nevada [abs.]: *New Mexico Bureau of Mines and Mineral Resources Bulletin* 131, p. 70.
- Dixon, G.L., Hedlund, D.C., and Ekren, E.B., 1972, Geologic map of the Pritchards Station quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-728, scale 1:48,000.
- Dohrenwend, J.C., Abrahams, A.D., and Turrin, B.D., 1987, Drainage development on basaltic lava flows, Cima volcanic field, southeast California, and Lunar Crater volcanic field, south-central Nevada: *Geological Society of America Bulletin*, v. 99, p. 405-413.
- Dohrenwend, J.C., Turrin, B.D., and Diggles, M.F., 1985, Topographic distribution of dated basaltic lava flows in the Reveille Range, Nye County, Nevada; implications for late Cenozoic erosion of upland areas in the Great Basin [abs.]: *Geological Society of America Abstracts with Programs*, v. 17, no. 6, p. 352.
- Edwards, G., and McLaughlin, W.A., 1972, Shell list no. 1-K-Ar and Rb-Sr age determinations of California, Nevada, and Utah rocks and minerals: *Isochron/West*, no. 3, p. 1-7.
- Ekren, E.B., Anderson, R.E., Rogers, C.L., and Noble, D.C., 1971, Geology of Northern Nellis Air Force Base Bombing and Gunnery Range, Nye County, Nevada: U.S. Geological Survey Professional Paper 651, 91 p.
- Ekren, E.B., Bath, G.D., Dixon, G.L., Healey, D.L., and Quinlivan, W.D., 1974, Tertiary history of Little Fish Lake Valley, Nye County, Nevada, and implications as to the origin of the Great Basin: *U.S. Geological Survey Journal of Research*, v. 2, no. 1, p. 105-118.
- Ekren, E.B., Hinrichs, E.N., Quinlivan, W.D., and Hoover, D.L., 1973a, Geologic map of the Moores Station quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-756, scale 1:48,000.
- Ekren, E.B., Rogers, C.L., and Dixon, G.L., 1973b, Geologic and Bouguer gravity map of the Reveille quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-806, scale 1:48,000.
- Ervine, W.B., 1972, The geology and mineral zoning of the Spanish Belt mining district, Nye County, Nevada: Stanford, Calif., Stanford University, Ph.D. dissertation, 258 p.
- Evernden, J.F., and James, G.T., 1964, Potassium-argon dates and the Tertiary floras of North America: *American Journal of Science*, v. 262, p. 945-974.
- Evernden, J.F., Savage, D.E., Curtis, G.H., and James, G.T., 1964, K-Ar dates and the Cenozoic mammalian chronology of North America: *American Journal of Science*, v. 262, p. 145-198.
- Ferguson, H.G., and Cathcart, S.H., 1954, Geologic map of the Round Mountain quadrangle, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-40, scale 1:125,000.
- Gardner, J.N., Eddy, A.C., Goff, F.E., and Graft, K.S., 1980, Reconnaissance geologic map of the northern Kawich and southern Reveille Ranges, Nye County, Nevada: Los Alamos Scientific Laboratory Map LA 8390, scale 1:62,500.
- Grabher, D.E., 1984, Union Carbide's Pilot Mountain project, Geologic setting and field trip guide in Johnson, J.L., ed., *Exploration for ore deposits of the American Cordillera*: Association of Exploration Geochemists, p. FT5-FT24.
- Gromme, C.S., McKee, E.H., and Blake, M.C., 1972, Paleomagnetic correlation of potassium-argon dating of Middle Tertiary ash-flow sheets in the eastern Great Basin, Nevada and Utah: *Geological Society of America Bulletin*, v. 83, no. 6, p. 1619-1638.
- Hambrick, D.A., 1984, Geochemistry and structure of Tertiary volcanic rocks in the southern Monte Cristo Range, Nevada: Tucson, Arizona, University of Arizona, M.S. thesis, 140 p.
- Hardyman, R.F., Poole, F.G., Kleinhampl, F.J., Turner, R.L., Plouff, Donald, Duval, J.S., Johnson, F.L., and Benjamin, D.A., 1977, Mineral resources of the Antelope Wilderness Study Area, Nye County, Nevada: U.S. Geological Survey Bulletin 1731-E, p. E1-E9, scale 1:50,000.
- John, D.A., 1987a, Geologic map of parts of the Morey and Fandango Wilderness Study Areas, Nye County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1847, scale 1:62,500.
- 1987b, Map showing the distribution and characteristics of plutonic rocks in the Tonopah 1° by 2° quadrangle, central Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1877-J, scale 1:250,000.
- 1988, Geologic map of Oligocene and Miocene volcanic rocks, Paradise Peak and western part of the Ione quadrangles, Nye County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-2075, scale 1:24,000, 2 sheets.
- 1992, Stratigraphy, regional distribution, and reconnaissance geochemistry of

- Oligocene and Miocene volcanic rocks in the Paradise Range and northern Pactolus Hills, Nye County, Nevada: U.S. Geological Survey Bulletin 1974, 67 p.
- John, D.A., and Kelleher, P.C., 1987, Bedrock geologic map of the Goldyke quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1963, scale 1:24,000.
- John, D.A., and McKee, E.H., 1987, K-Ar ages of granitic plutonism and hydrothermal alteration in the western part of the Tonopah 1° x 2° quadrangle, Nevada: *Isochron/West*, no. 48, p. 16-18.
- John, D.A., and Robinson, A.C., 1989, Rb-Sr whole-rock isotopic ages of granitic plutons in the western part of the Tonopah 1° by 2° quadrangle, Nevada: *Isochron/West*, no. 53, p. 20-27.
- John, D.A., Thomason, R.E., and McKee, E.H., 1989, Geology and K-Ar geochronology of the Paradise Peak Mine and the relationship of pre-Basin and Range extension to early Miocene precious-metal mineralization in west-central Nevada: *Economic Geology*, v. 84, p. 631-649.
- Kay, Marshall, and Crawford, J.P., 1964, Paleozoic facies from the miogeosynclinal to the eugeosynclinal belt in thrust slices, central Nevada: *Geological Society of America Bulletin*, v. 75, no. 5, p. 425-454.
- Keith, W.J., 1987a, Preliminary geologic map of the Big Ten Peak quadrangle, Nye County, Nevada: U.S. Geological Survey Open-File Report 87-7, scale 1:62,500.
- 1987b, Preliminary geologic map of the McCann 15' quadrangle, Nye County, Nevada: U.S. Geological Survey Open-File Report 87-425, scale 1:62,500.
- Kleinhampl, F.J., and Ziony, J.I., 1985, Geology of northern Nye County, Nevada: Nevada Bureau of Mines and Geology Bulletin 99A, 172 p.
- Marvin, R. F., and Dobson, S. W., 1979, Radiometric ages: compilation B, U.S. Geological Survey: *Isochron/West*, no. 26, p. 3-32.
- Marvin, R.F., Mehnert, H.H., and McKee, E.H., 1973, A summary of radiometric ages of Tertiary volcanic rocks in Nevada and eastern California. Part III: Southeastern Nevada: *Isochron/West*, no. 6, p. 1-30.
- McKee, E.H., and John, D.A., 1987, Sample locality map and potassium-argon data for Cenozoic igneous rocks and minerals in the Tonopah 1° x 2° quadrangle, central Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1877-K, scale 1:250,000.
- Mills, B.A., Boden, D.R., and Sander, M.V., 1988, Alteration and precious metal mineralization associated with the Toquima caldera complex, Nye County, Nevada, in Schafer, R.W., Cooper, J.J., and Vikre, P.G., eds., Bulk mineable precious metal deposits of the western United States, Symposium proceedings: Reno, Geological Society of Nevada, p. 303-331.
- Molinari, M.P., 1984, Late Cenozoic structural geology of Stewart and Monte Cristo Valleys, Walker Lane of west central Nevada, in Lintz, Joseph, Jr., ed., *Western geological excursions*, volume 4, 1984 Annual Meeting of the Geological Society of America: Boulder, Geological Society of America, p. 219-231.
- Moore, S.W., 1981, Geology of a part of the southern Monte Cristo Range, Esmeralda County, Nevada: San Jose, California., San Jose State University, M.S. thesis, 157 p.
- Oldow, J.S., 1981, Structure and stratigraphy of the Luning allochthon and the kinematics of allochthon emplacement, Pilot Mountains, west-central Nevada: *Geological Society of America Bulletin*, Part I, v. 92, p. 888-911.
- Oldow, J.S., and Bartel, R.L., 1987, Early to Middle(?) Jurassic extensional tectonism in the western Great Basin: Growth faulting and synorogenic deposition of the Dunlap Formation: *Geology*, v. 15, p. 740-743.
- Phariss, E.I., 1974, Geology and ore deposits of the Alpine mining district, Esmeralda County, Nevada: Reno, Nevada, University of Nevada, M.S. thesis, 114 p.
- Quinlivan, W.D., and Rogers, C.L., 1974, Geologic map of the Tybo quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-821, scale 1:48,000.
- Sargent, K.A., and McKee, E.H., 1969, The Bates Mountain Tuff in northern Nye County, Nevada: U.S. Geological Survey Bulletin 1294-E, p. E1-E12.
- Shaver, S.A., 1984, The Hall (Nevada Moly) molybdenum deposits, Nye County, Nevada: Geology, alteration, mineralization and geochemical dispersion: Stanford, California, Stanford University, Ph.D. dissertation, 261 p.
- Shawe, D.R., 1981a, Geologic map of the Round Mountain quadrangle, Nye County, Nevada: U.S. Geological Survey Open-file Report 81-515, scale 1:24,000.
- 1981b, Geologic map of the Manhattan quadrangle, Nye County, Nevada: U.S. Geological Survey Open-File Report 81-516, scale 1:24,000.
- 1986, Stratigraphic nomenclature of volcanic rocks near Manhattan, southern Toquima Range, Nye County, Nevada: U.S. Geological Survey Bulletin 1775-A, p. A1-A8.
- Shawe, D.R., Marvin, R.F., Andriessen, P.A.M., Mehnert, H.H., and Merritt, V.M., 1986, Ages of igneous and hydrothermal events in the Round Mountain and Manhattan gold districts, Nye County, Nevada: *Economic Geology*, v. 81, no. 2, p. 388-407.

- Silberling, N.J., 1959, Pre-Tertiary stratigraphy and Upper Triassic paleontology of the Union district, Shoshone Mountains, Nevada: U.S. Geological Survey Professional Paper 322, 67 p.
- , 1984, Map showing localities and correlations of age-diagnostic lower Mesozoic megafossils, Walker Lake 1° x 2° quadrangle, Nevada and California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1382-O, scale 1:250,000.
- Silberling, N.J., and John, D.A., 1989, Geologic map of pre-Tertiary rocks of the Paradise Range and southern Lodi Hills, west-central Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-2065, scale 1:24,000.
- Silberling, N.J., and Roberts, R.J., 1962, Pre-Tertiary stratigraphy and structure of northwestern Nevada: Geological Society of America Special Paper 72, 58 p.
- Silberman, M.L., Bonham, H.F., Jr., Garside, L.J., and Osborne, D.H., 1975, New K-Ar ages of volcanic and plutonic rocks and ore deposits in western Nevada: *Isochron/West*, no. 13, p. 13-21.
- Silberman, M.L., and McKee, E.H., 1971, K-Ar ages of granitic plutons in north-central Nevada: *Isochron/West*, no. 71-1, p. 15-32.
- , 1972, A summary of radiometric age determinations on Tertiary volcanic rocks from Nevada and eastern California: Part II, western Nevada: *Isochron/West*, no. 4, p. 7-28.
- Snyder, R.P., Ekren, E.B., and Dixon, G.L., 1972, Geologic map of the Lunar Crater quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-700, scale 1:48,000.
- Speed, R.C., 1977, An appraisal of the Pablo Formation of presumed Late Paleozoic age, central Nevada, in Stewart, J.H., Stevens, C. H., and Fritsche, A.E., eds., *Paleozoic paleogeography of the western United States: Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogeography Symposium 1*, p. 315-324.
- Speed, R.C., and Armstrong, R.L., 1971, Potassium-argon ages of some minerals from igneous rocks of western Nevada: *Isochron/West*, no. 1, p. 1-8.
- Speed, R.C., and McKee, E.H., 1976, Age and origin of the Darrough Felsite, southern Toiyabe Range, Nevada: U.S. Geological Survey *Journal of Research*, v. 4, p. 75-81.
- Steiger, R.H., and Jager, E., 1977, Subcommittee on geochronology: Convention on the use of decay constants in geo- and cosmo-chronology: *Earth and Planetary Sciences Letters*, v. 36, p. 359-362.
- Streckeisen, A.L., 1976, Plutonic rocks--classification and nomenclature: *Geotimes*, v. 18, no. 10, p. 26-30.
- Taylor, D.G., Smith, P.L., Laws, R.A., and Guex, Jean, 1983, The stratigraphy and biofacies trends of the Lower Mesozoic Gabbs and Sunrise Formations, west-central Nevada: *Canadian Journal of Earth Sciences*, v. 20, p. 1598-1608.
- Vitaliano, C.J. and Vitaliano, D.B., 1972, Cenozoic volcanic rocks in the southern Shoshone Mountains and Paradise Range, Nevada: Geological Society of America *Bulletin*, v. 83, p. 3269-3280.
- Whitebread, D.H., Brem, G.F., Andrews, T.D., and Silberling, N.J., 1988, Preliminary geologic map of the eastern half of the Ione quadrangle, Nye County, Nevada: U.S. Geological Survey Open-File Report, 88-48, scale 1:62,500.
- Whitebread, D.H., and Hardyman, R.F., 1987, Preliminary geologic map of part of the Cedar Mountains and Royston Hills, Esmeralda and Nye Counties, Nevada: U.S. Geological Survey Open-File Report 87-613, scale 1:62,500.



**Table 1. Summary of isotopic age data in the Tonopah quadrangle**  
[K-Ar ages published before 1977 are corrected using the constants recommended by IUGS Subcommittee on Geochronology (Steiger and Jager, 1977)]

Map unit	Age (Ma)	Area	Reference
Ts <sub>4</sub>	11-12	Cedar Mtns.	Evernden and others, 1964.
	13	Monte Cristo Range	Evernden and James, 1964.
	16-17	San Antonio Mtns.	Bonham and Garside, 1979.
Qb	0.1-1	Pancake Range	Dohrenwend and others, 1987.
Tba	20-12	Paradise Range	McKee and John, 1987; John and others, 1989.
	7	Monte Cristo Range	McKee and John, 1987.
	15-16	San Antonio Mtns.	Bonham and Garside, 1979; Armstrong and others, 1972.
	16	Thunder Mtn.	Bonham and Garside, 1979.
	10	Squaw Hills	Ekren and others, 1973a.
	4-6	Reveille Range	Ekren and others, 1973b; Dohrenwend and others, 1985.
	20	Toiyabe Range	McKee and John, 1987.
Ta <sub>4</sub>	17-19	Paradise Range	McKee and John, 1987.
	20	Royston Hills	McKee and John, 1987.
	12-20	Monte Cristo Range	McKee and John, 1987; Silberman and others, 1975; Silberman and McKee, 1972.
	17	Indian Valley	McKee and John, 1987.
	21	San Antonio Mtns.	Bonham and Garside, 1979.
Tr <sub>4</sub>	16-19	Paradise Range	McKee and John, 1987.
	7-19	Monte Cristo Range	Silberman and others, 1975; McKee and John, 1987.

	20	Toiyabe Range	McKee and John, 1987.
	15-19	San Antonio Mtns.	Bonham and Garside, 1979.
	19	Reveille Range	Ekren and others, 1973b.
Ta <sub>3</sub>	22	Monte Cristo Range	Hambrick, 1984.
	23	Toquima Range	Shawe and others, 1986.
Tr <sub>3</sub>	22	Lone Mtn.	Bonham and Garside, 1979.
Ta <sub>2</sub>	24-26	Paradise Range	McKee and John, 1987; John and others, 1989.
	26-27	Monitor Range	D.R. Shawe, written commun., 1986.
Tr <sub>2</sub>	24-28	Toquima Range	D.R. Shawe, written commun., 1986; McKee and John, 1987.
	26-30	Monitor Range	McKee and John, 1987.
Tr <sub>1</sub>	38	Park Range	Dixon and others, 1972.
Tt <sub>4</sub>	17	Monte Cristo Range	McKee and John, 1987.
Tf	18-21	San Antonio Mtns.	Bonham and Garside, 1979.
Tt <sub>3</sub>	22-24	Paradise Range	McKee and John, 1987; John and others, 1989.
	22	Shoshone Mtns.	McKee and John, 1987.
Tsw	20-22	Monitor Range	Kleinhampl and Ziony, 1985; McKee and John, 1987.
Ttt	21-23	Paradise Range	McKee and John, 1987.
	22	Toiyabe Range	McKee and John, 1987; Silberman and McKee, 1972.
	22	Shoshone Mountains	McKee and John, 1987.

Tgw	23-24	Pancake Range	Snyder and others, 1972.
Tbm	23	Crested Wheat Ridge	Sargent and McKee, 1969.
	25	Hot Creek Range	Deino, 1989.
Tt <sub>2</sub>	26-30	Cedar Mtns.	McKee and John, 1987.
	26-29	Royston Hills	McKee and John, 1987.
	30	Shoshone Mtns.	McKee and John, 1987.
	24-32	Toquima Range	Boden, 1986; McKee and John, 1987; Mills and others, 1988.
	24-27	Monitor Range	McKee and John, 1987.
	28-29	Crested Wheat Ridge	Dixon and others, 1972; Marvin and others, 1973.
	31	Squaw Hills	Ekren and others, 1973a.
	31	Halligan Mesa	Ekren and others, 1973a.
	26	Pancake Range	Ekren and others, 1973b.
Tad	25	Paradise Range	McKee and John, 1987.
	24.5	Shoshone Mountains	Armstrong, 1970.
Tpc	25	Toquima Range	Shawe and others, 1986; Shawe, 1986.
Tsp	25-28	Crested Wheat Ridge	Sargent and McKee, 1969;
	22-28	Pancake Range	Marvin and others, 1973.
Trr	25	Toquima Range	Shawe and others, 1986.
Tkc	25-26	Hot Creek Range	Quinlivan and Rogers, 1974.
Tmj	25-27	Toquima Range	D.R. Shawe, written commun., 1986; Boden, 1986; McKee and John, 1987; Marvin and others, 1973; Mills and others, 1988.

Tbt	25-27	Monitor Range	D.R. Shawe, written commun., 1986; McKee and John, 1987.
Tm	28	Heart Hills	Ekren and others, 1973a.
	28	Palisade Mesa	Marvin and others, 1973.
	27-29	Hot Creek Range	Quinlivan and Rogers, 1974.
Thc	30-32	Hot Creek Range	Marvin and others, 1973;
	30-31	Squaw Hills	Ekren and others, 1973a.
Twb	31-32	Park Range	Gromine and others, 1972; Marvin and others, 1973.
Twm	32-33	Halligan Mesa	Ekren and others, 1973a.
	32	Squaw Hills	Ekren and others, 1973a.
Tg	31	Toiyabe Range	Speed and McKee, 1976.
	36-37	Toquima Range	Shawe and others, 1986.
	26	Monitor Range	John, 1987b.
TKg	56	Toiyabe Range	Speed and McKee, 1976.
Kg	102	Lodi Hills	John, 1987b; John and Robinson, 1989.
	74	Paradise Range	John and McKee, 1987.
	83	Pilot Mtns.	Grabher, 1984.
	80	Rock Hill area	Silberman and others, 1975.
	66-79	San Antonio Mtns.	Silberman and others, 1975; Shaver, 1984.
	67-86	Lone Mtn.	Silberman and others, 1975; John and Robinson, 1989.

	68-100	Toiyabe Range	John and McKee, 1987; John, 1987b; John and Robinson, 1989; Marvin and Dobson, 1979.
	75-95	Toquima Range	Shawe and others, 1986; Silberman and McKee, 1971; Ervine, 1972; Edwards and McLaughlin, 1972; John and Robinson, 1989.
Kd	113	Lone Mtn.	Bonham and Garside, 1979.
Jg	157	Toquima Range	Silberman and McKee, 1971.
	198	Monte Cristo Range	Silberman and others, 1975.
JHg	199-206	Royston Hills	Speed and Armstrong, 1971; John, 1987b; John and Robinson, 1989.
Hg	221	San Antonio Mtns.	John and McKee, 1987.

