Geologic map of the New River quadrangle and part of the Daisy Mountain quadrangle, Maricopa and Yavapai Counties, Arizona

by

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DESCRIPTION OF MAP UNITS

[Volcanic and hypabyssal plutonic rocks are named according to the chemical classification recommended by the IUGS (Le Bas and others, 1986) and the analyses given in tables 1 and 2; Description and discussion of geology presented after unit descriptions]

a **Artificial fill**—Boulder to pebble gravel, sand, and silt used as fill beneath highways and in earth-fill dams.

Qal **Alluvium (Holocene)**—Gravel, sand, and silt on floodplains of steams and washes. Boulders of basalt as much as 2 m in diameter in Boulder Creek drainage west of the Agua Fria River. Thickness 1-5 m.

Qtc **Talus and colluvium (Holocene and Pleistocene)**—Angular fragments of rock in various proportions of sand and silt matrix. Deposits derived from basalt contain blocks as large as 8 m in diameter on west side of Wild Burro Mesa. Deposits on New River Mesa Basalt of Gomez (1979) are composed of angular boulders 1-2 m in diameter. Locally cemented by caliche. Grades into pediment gravel downslope. Thickness 1-10 m.

Ql **Landslide (Pleistocene)**—Blocks of rock in various proportions of silt and sand matrix. Irregular surface topography on the most recent landslides. Landslide 0.7 km north of Gavilin Peak in southeast part of area contains angular blocks of trachydacite as much as 1.2 m in diameter cemented by caliche. Thickness 3-10 m.

Qpg **Pediment gravel (Holocene and Pleistocene)**—Gravel, sand, and silt mantling surfaces cut on bedrock. Deposits derived from the New River Mesa Basalt of Gomez (1979) contain boulders as much as a meter in diameter. Clasts generally subangular to subrounded but include rounded to subrounded clasts where derived from Tertiary conglomerate. Surfaces are 5 to 40 m above drainage and are of several ages. Oldest and highest surface in north central part of the area is graded to the highest terrace (Qtg_3) along the Agua Fria River. Thickness 1-6 m.

Qu **Alluvium and pediment gravel (Holocene and Pleistocene)**—East of New River. Thickness 1-3m.

Qd **Debris flows (Holocene and Pleistocene)**—Clast-supported to matrix-supported gravel containing angular clasts 10 cm-1.5 m in diameter, but locally as much as 3 m, in a sandy to silty matrix.

Qtg **Terrace gravel (Pleistocene)**—Pebble to boulder gravel, sand, and silt on terraces 5 to 40 m above drainage, mostly along the New and Agua Fria Rivers. Contains rounded to subrounded boulders of basalt and, in the northeastern part of the area, Proterozoic granite and rhyolite as much as 2 m in diameter and a variety of other rock types from upvalley. Where different terraces occur in the same area, they are labeled Qtg_1, Qtg_2, Qtg_3 and Qtg_4 from lowest to highest. Thickness 1-5 m.

Qoa **Older alluvium (Holocene and Pleistocene)**—Boulder, cobble, and pebble gravel, sand and silt along tributary washes. Surface above modern floodplain. Maximum thickness 10 m.

Qgm **Sand, gravel and silt (Pleistocene)**—Various proportions of sand, boulder to pebble gravel, and silt at margin of basin in southwestern part of area. Boulders of basalt as much as 1.5 m in diameter near north margin of deposit. Clast diameter decreases to south. Corresponds to unit M1 of Demsey (1988) inferred to be of middle to early Pleistocene age. Thickness 5-30 m.

Qgo **Older sand, gravel, and silt (Pleistocene)**—Various proportions of sand, boulder to pebble matrix supported gravel, and silt at margin of basin in southwestern part of area. Caliche cement widespread. Boulders of basalt as much as 1.5 m in diameter near north margin of deposit. Clast diameter decreases to south. Abundant fragments of pedogenic carbonate on surface remnants. Also caps surfaces in eastern part of area. Corresponds to unit o of Demsey (1988) inferred to be of early Pleistocene age. Thickness 5-30 m.

Qlc **Landslide and colluvium (Pleistocene)**—Boulders, cobbles, and pebbles of basalt containing varied proportions of sand and silt matrix. Caps small hills on west slope of Wild Burro Mesa in west central part of area as much as 50 m above slope mantled by Holocene talus and colluvium and conceals tuff and conglomerate unit (Ttc). Includes some younger colluvium derived from this unit. A deposit included in this unit in the eastern part of the area contains angular pebbles, cobbles, and boulders of basalt of New River Mesa of Gomez (1979), is cemented by caliche where exposed in roadcuts, and lacks typical landslide morphology. Maximum thickness 10 m.

QTg **Boulder gravel, sand, and silt (Pleistocene or Pliocene)**—Gravel containing rounded boulders of basalt, granite, diorite, rhyolite, and vitrophyre as much as 2 m in diameter capping terraces about 60 m above the New and Agua Fria rivers. Generally cemented by caliche. Thickness 3-10 m.

Tgy **Boulder gravel (Pliocene or late Miocene)**—Gravel containing rounded boulders of metarhyolite, granite, and basalt as much as 2 m in diameter, as well as a variety of other rock types, capping ridges 120 m above drainage in the northern part of the area. Debris from deposit conceals lower contact and forms colluvial and pediment deposits downslope. In southwestern part of area includes highly dissected gravel deposits having a zone of caliche several meters thick near the top (Demsey, 1988). Thickness 3-10 m in the northern part of the area and at least 20 m thick in the southern part.

Tcs **Conglomerate and sandstone (Miocene)**—Gray-weathering, pale gray to brownish gray pebble, cobble, and boulder conglomerate and sandstone in west-central part of area. Contains boulders as much as 1 m in diameter. Beds typically lenticular and 1-3 m thick. Well-bedded siliceous limestone and calcareous sandstone interbedded with conglomerate near base. Thickness as much as 60 m.

Tm **Siltstone and claystone (Miocene)**—Pale brown to pale reddish brown and moderate gray siltstone, claystone, and mudstone containing some beds of silty limestone and a few beds of pebble to cobble conglomerate as much as 0.3 m thick. Marginal lacustrine facies rock and apparently equivalent to upper part of siliceous limestone and limestone (Tl) to the east. In west central part of area. Thickness about 30 m.

Tl **Siliceous limestone and limestone (Miocene)**—Evenly bedded, very light gray to white siliceous limestone and dolomite and minor calcareous sandstone. Beds 1 cm to 2m thick. Locally contains granules and pebbles of basalt, algal structures, and mudcracks. Gypsiferous or clayey in places. In west central part of area. Maximum thickness more than 80 m.

Tsc **Sandstone and conglomerate (Miocene)**—Pale brownish gray, gray, pale gray to yellowish gray sandstone, conglomerate, and tuffaceous conglomerate. A few beds of siliceous limestone near the top. Upper part calcareous sandstone and pebble to cobble conglomerate, and mudstone having beds 2-10 cm thick. At the base, conglomerate contains boulders of New River Mesa Basalt of Gomez (1979) as much as 1 m in diameter. Some of the basal sequence is a sedimentary breccia probably deposited as debris flows. Alluvial facies rock that underlies and is partly equivalent to siliceous limestone and limestone (Tl) in west central part of area. Maximum thickness 60 m.

Tnb **New River Mesa Basalt of Gomez (1979) (Miocene)**—Dark brownish-gray-weathering, coarse-grained basalt containing plagioclase laths as much as 5 mm long and olivine and pyroxene 0.2-2 mm in diameter. Rock is vuggy and has vesicles in ellipsoidal or pipe-shaped concentrations as much as 1 m long and 0.2 m in diameter. These characteristics are like those described by Gomez (1979) and Jagiello (1987) for this unit in areas south and east of the map area. Locally has basalt rubble at base. K-Ar whole-rock dates of 14-15 Ma south and east of the area (Scarborough and Wilt (l979). Maximum thickness 70 m.

Ta **Trachyandesite flow and lahar (Miocene)**—Lahar containing boulders of trachyandesite as much as 1 m in diameter overlain by light gray-weathering altered trachyandesite. Probably derived from plug immediately northeast in the Squaw Creek Mesa quadrangle. Trachyandesite consists of euhedral to subhedral phenocrysts of reddish brown hornblende 0.5 mm long but as long as 2 mm and microlites of plagioclase as long as 0.3 mm in a matrix of partly devitrified glass. Caps hill east of Moore Gulch at north edge of area. Lahar about 10 m thick; flow about 10 m thick.

Tpt **Porphyritic trachydacite (Miocene)**—Hornblende-biotite trachydacite in plug forming Gavilan Peak. Pale brown-weathering, light gray rock containing hornblende phenocrysts generally 1-5 mm and rarely as much as 1 cm long, sparse biotite phenocrysts as much as 2 mm in diameter and plagioclase 5 to 7 mm in diameter. Hornblende and biotite are mostly altered to opaque mineral. Plagioclase is An 30-35. Matrix of plagioclase, K-feldspar, opaque mineral, carbonate, and glass. Accessory apatite and monoclinic pyroxene. K-Ar date of biotite is 21.55±0.5 Ma (Damon and others, 1996).

Ttv **Pyroxene trachydacite (Miocene)**—Light gray- to light brownish gray-weathering aphanitic rock containing a few feldspar phenocrysts and having vitophyre at base. Phenocrysts of plagioclase An 32 as much as 0.4 mm long and less abundant phenocrysts of monoclinic pyroxene as much as 0.12 mm in diameter in a very fine-grained matrix rich in plagioclase and containing pyroxene and opaque mineral. Restricted to small area 0.7 km east of Gavilan Peak and probably is extrusive phase of the Gavilan Peak plug.

Tb **Basaltic rocks (Miocene and Oligocene)**—Olivine, olivine-pyroxene, and pyroxene basalt, trachybasalt, basaltic trachyandesite, basaltic rubble, and basaltic tuff. Weathers light gray, light olive gray, light greenish gray, and dark gray. Altered varieties, rubble, and tuff are grayish red to reddish brown. Contains varied proportions of olivine, commonly altered to 'iddingsite', as phenocrysts 1-5 mm in diameter, green to black monoclinic pyroxene as phenocrysts 1-5 mm in diameter, and plagioclase as phenocrysts 0.5-3 mm long. Locally contains quartz xenocrysts. Rare xenoliths of quartzite and greenschist. Some rocks are highly altered and contain calcite-filled amygdules and many calcite veins. Rubble zones have matrix of calcite. In some flows, quartz or zeolites fill amygdules. Contains thin interbeds of conglomerate, sandstone, and tuff generally less than 10 m thick and commonly has white tuff at base, which is mapped with the unit where it is thin or poorly exposed. Unit contains a few beds of reddish brown to grayish red basaltic sandstone and conglomerate. Basalt underlying siliceous limestone (Tl) near Lake Pleasant is cut by moderately dipping to subhorizontal veins of colloform silica, which are locally so numerous that pieces and masses of basalt are inclusions in a siliceous matrix. K-Ar whole-rock dates of 20±1.3 Ma near the base of the section in sec 11, T. 7 N., R. 2 E.. (Eberly and Stanley, 1978) and 26.5±0.6 Ma in Tule Wash, Sec. 10, T. 7 N., R. 1 E.. (Scarborough, and Wilt, 1979). Maximum thickness 200 m.

Ttc **Tuff and conglomerate (Miocene and Oligocene)**—White to very pale gray lithic and crystal-lithic tuff, welded tuff, tuffaceous conglomerate and conglomerate at the base of and interbedded with basaltic rocks (Tb). In western part of area on the west side of Wild Burro Mesa, on the flanks of Dutch Butte and the mesa to the south, upper part consists of pale reddish brown sandstone, conglomerate, and tuffaceous conglomerate containing clasts of Tertiary felsic volcanic rocks and Precambrian greenschist, metachert, metarhyolite, and quartz. In many places the upper part is underlain by flows of olivine basalt, which are 10 m or less thick and not mapped separately in most places. Lower part is lithic tuff composed mostly of fragments of altered pumice but locally containing fragments of felsic volcanic rock or basalt. In the Indian Mesa-Wild Burro Mesa area basal part of the section is rich in tuff containing fragments of altered basalt. Beds range in thickness from 0.5 cm to 10 m. In the eastern part of

the area unit contains 1 to 4 beds of welded tuff 0.5-2.5 m thick. Unit locally contains one or more unconformities. Deposited on an irregular surface, and, locally, the dips reflect those irregularities. Except for the conglomerate beds, forms a very clay-rich soil. Maximum thickness 200 m.

Tc **Conglomerate and sandstone (Miocene)**—Pebble and cobble conglomerate, sandstone, tuffaceous sandstone, sandy tuff, and tuff in north part of area near Interstate Highway 17. Contains lenticular beds of tuffaceous, siliceous, palludal limestone and pale gray to pale brown well-bedded clay. Near top of unit capping the hills near the township line and east of Interstate Highway 17, pale brownish gray pebble to cobble conglomerate locally containing boulders as much as 0.4 m in diameter in beds 2 cm to 0.5 m thick and containing clasts of Precambrian rhyolite and lesser amounts of Precambrian metavolcanic rock and metachert derived from east of the area. In lower part conglomerates are generally finer grained and contain beds of tuff. Sedimentary breccia of angular fragments of latite locally containing some fragments of Precambrian metavolcanic rock present in unit where it overlies trachyandesite and trachyandesite breccia (Tt, Ttb). In western exposures near the north edge of the area, unit contains clasts of granitic rock and gneiss derived from the north or northwest. Western part of the unit contains some basalt cobble to boulder beds. Gradational contacts with tuff and conglomerate unit (Ttc) underlying and at equivalent stratigraphic level to the northwest. Maximum thickness about 180 m.

Tr **Rhyolite (Miocene)**—Fine-grained and siliceous. Composed of sparse phenocrysts of quartz and plagioclase and rare phenocrysts of monoclinic pyroxene and brown hornblende in a matrix of fragments of glassy and cryptocrystalline material. Forms a pipe in basalt (Tb) 60 m in diameter on boundary of Secs. 1 and 2, T. 6 N., R. 1 E. and a dike to the north.

Tbt **Basaltic tuff (Miocene and Oligocene)**—In northwest part of the area is pale red lithic tuff. Grades upward and to the east and northeast into white tuff containing small proportions of altered basaltic material and larger proportions of altered pumice. In east-central part of the area, east of the New River, unit consists of red and grayish red tuff and lapilli tuff that formed part of a cinder cone. Rocks of this unit are soft and form clay-rich soils. Maximum thickness 100 m.

Tba **Basaltic vent-facies rock (Miocene and Oligocene)**—Grayish red, pale grayish red to reddish-brown altered basalt and crudely bedded agglomerate, cinders and lapilli tuff. Calcite and silica commonly in matrix of agglomerate. Mapped in northwest part of area. Apparent thickness as much as 50 m but may be thicker.

Tbta **Basaltic trachyandesite (Miocene and Oligocene)**—Brownish gray, generally altered rock containing amphibole phenocrysts 1-3 mm long in a fine-grained matrix. Contains sparse phenocrysts of plagioclase An50-60 showing normal and, locally, reverse zoning. Amphibole phenocrysts and less abundant biotite phenocrysts are altered. Matrix consists of plagioclase, carbonate, opaque mineral, and altered amphibole and biotite. Forms plug in southwest corner of area.

Tt **Trachyandesite (Oligocene)**—Pale-orangish gray to yellowish gray-weathering, very pale brownish gray biotite trachyandesite or trachydacite containing abundant mafic xenoliths 0.5-6 cm in diameter. Contains sparse phenocrysts of biotite and monoclinic pyroxene as much as 1 mm in diameter in a matrix of plagioclase and pyroxene microlites, glass, and opaque mineral. Mafic xenoliths are biotite-monoclinic pyroxene, garnet-monoclinic pyroxene-amphibole, and monoclinic pyroxene-anorthite-garnet-amphibole. $^{40}Ar/^{39}Ar$ date on biotite 26.5 ±0.4 Ma (Leighty, 1997). Interpreted to be exogenous volcanic domes partly mantled by and partly underlain by trachyandesite breccia (Ttb).

Ttb **Trachyandesite breccia (Oligocene)**—Flow and tuff breccia composed of angular fragments of biotite latite containing abundant xenoliths. Overlies and underlies trachyandesite unit (Tt). Breccia also forms thin, steeply dipping zones representing faults and fractures (most not shown on map).

Xq **Quartz vein (Early Proterozoic)**—massive white quartz. In and adjacent to felsic metaintrusive rock (Xfi) in SE ¼ Sec. 29, T 7 N., R. 2 E.

Xfi **Felsic metaintrusive rock (Early Proterozoic)**—White to gray, fine- to medium-grained, partly foliated metagranite, metasyenite and metarhyolite. Quartz veins common. Forms sills 1 to 200 m thick parallel with foliation and bedding in the east central part of the area in the phyllitic slate, slate, and graywacke (Xps) and phyllite, marble, and greenschist (Xpm) and a few thin, unmapped sills west of and close to the Moore Gulch fault zone south of Moore Gulch. Some of the rocks in this unit may be older than shown here.

Xag **Aplite and leucocratic granite (Early Proterozoic)**—Pinkish gray to moderate orange pink to light brownish gray, locally vuggy aplite, fine-grained granite, and porphyritic granite. Contains euhedral to subhedral plagioclase (An5) phenocrysts as long as 4 mm and anhedral to subhedral potassic feldspar as much as 1 mm in diameter. Much of the quartz and potassic feldspar forms micrographic intergrowths in the matrix. Minor amounts of biotite and hornblende in unit east of the area. Intrudes low-silica rhyolite near the New River in Sec 4, T. 7 N., R. 3 E..

Xp **Altered metaandesite and phyllite (Early Proterozoic)**—Grayish brown and brownish gray-weathering chlorite-sericite phyllite containing massive beds, lenses, and pods of calcite chlorite rock. Many of the mafic rocks have some grains of euhedral altered plagioclase, and some have fragmental texture. Much of the rock in the unit is interpreted to as metamorphosed highly altered andestitic flows and tuffs. Contacts with strongly deformed high-silica rhyolite (Xrh) gradational in many places suggesting that some rocks in the unit may be altered and metamorphosed rhyolite.

Xrh **High silica rhyolite and metarhyolite (Early Proterozoic)**—White, fine-grained, porphyritic rhyolite, metarhyolite, and quartz-feldspar and sericite-quartz feldspar gneiss probably derived from crystal-vitric tuff, crystal-lithic tuff, and some flows. Euhedral to anhedral phenocrysts of quartz in many rocks mostly 0.5-1 mm but locally as much as 2 mm diameter; euhedral to anhedral phenocrysts of plagioclase as much as 2 mm long and biotite as much as 0.2 mm long in a few rocks. Contains some 0.5 cm to several m thick lenses of quartz and chert locally having some carbonate and FeO minerals. Has flattened pumice fragments generally 0.5-3 mm, but locally as much as 8 mm long, which lie in the plane of foliation in well foliated rocks and along bedding planes elsewhere. Flow layering in some parts of unit. Local flow breccia and lahar. Sparse lenses of rhyolite conglomerate as much as 6 m thick and of phyllite probably derived from siltstone or shale.

Xrl **Low silica rhyolite (Early Proterozoic)**—tuffs and flows. Medium light gray, brownish gray, and medium dark gray porphyritic rhyolite containing phenocrysts of altered plagioclase as much as 5 mm long in a cryptocrystalline matrix probably derived from glass. Some rocks contain phenocrysts of hornblende or altered hornblende, and some contain chlorite. Compaction structures are common and flow structure and lithophysae rare. Contains lenses of pebble to boulder conglomerate. Where adjacent to phyllitic slate, slate, and graywacke (Xps) has fragments of slate in coarse grained lithic tuff and is stratigraphically younger. South of the New River where overlain by Xrh, 1-3 m purplish gray slate and phyllite is along the contact.

Xps **Phyllitic slate, slate, and graywacke (Early Proterozoic)**—Gray, dark gray, medium bluish gray, purplish gray, dark grayish red, and pale grayish red very fine-grained phyllite or intensely cleaved slate and siltstone containing locally graded beds of lithic sandstone and, rarely, pebble conglomerate. Channeling at base of some sandy beds. Pebbles and sandstone grains are

fragments of phyllitic slate. Massive to well-bedded in beds 0.5-8 cm thick; sandstone beds and lenses as much as 1.5 m thick. Locally quartz veins, lenses, and knots as much as 16 cm thick in exposures of unit in Secs 17, 18, 20, and 21, T. 7 N., R. 3 E.

Xrd **Metarhyolite (Early Proterozoic)**—Very light gray, light gray, and yellowish gray foliated metarhyolite containing auhedral to subhedral phenocrysts of plagioclase as much as 2 mm long and less common euhedral phenocrysts of quartz as much as 0.5 mm in diameter in a matrix of very fine-grained sericite, quartz, and feldspar, and some rocks containing minor amounts of chlorite and/or biotite.

Xgg **Greenschist, greenstone, and phyllite (Early Proterozoic)**—Greenschist, greenstone, porphyritic greenstone, metadacite, biotite-chlorite-sericite phyllite, chlorite-epidote-sericite phyllite. Includes subordinate phyllitic slate, sericite phyllite, thin-bedded greenschist, grayish-brown marble, sandstone, thin-bedded phyllitic shale and siltstone, and rare quartz-feldspar gneiss. Much of the greenstone and greenschist was probably derived from andesitic, basaltic, and, less commonly, dacitic flows. Rocks having fragmental texture probably have a lithic tuff or crystal-lithic tuff protolith. Rocks containing clasts of leucogranite or siliceous metavolcanic or hypabyssal rock probably derived from tuffaceous conglomerate and conglomeratic tuff. Phyllites probably derived from tuff, tuffaceous shale, and shale. Contains scattered small intrusions of hornblende diorite or gabbro, which are sheared and recrystallized to various degrees. Many rocks contain euhedral to subhedral phenocrysts of plagioclase as much as 4 mm long, and some contain anhedral crystal fragments of plagioclase. The plagioclase is commonly sausseritized and altered to albite. A few rocks contain subhedral phenocrysts and anhedral crystal fragments of quartz as much as 0.7 mm in diameter. Contains concordant bodies of felsic igneous rock generally less than 10 m thick and 100 m long containing plagioclase and, less commonly, quartz phenocrysts in a very fine-grained groundmass of sericite, quartz, and feldspar. A few of the metavolcanic rocks contain biotite, especially exposures either side of the New River south of the community of New River. Local lenses of metachert contain varied amounts of opaque minerals, and rock adjacent to the lenses commonly is altered to pale brownish gray or pale reddish brown sericite-quartz-feldspar phyllite.

Xgr **Graywacke, conglomerate, greenschist, and siltstone (Early Proterozoic)**—Dark greenish-gray to greenish-gray graywacke, conglomerate, greenschist, greenstone, thinly bedded siltstone and fine-grained sandstone, and greenish gray to pale yellowish gray sandstone or tuffaceous sandstone. Some graywacke is very calcareous and locally contains a few thin lenses of marble. Conglomerates contain clasts of andesite and, less commonly, of rhyolite as large as 0.3 m in diameter. Unit contains scattered lenses of rhyolite generally less than 100 long and 10 m thick. These bodies may have been intrusions into the sedimentary and volcanic rocks rather than flows. Rhyolite clasts in conglomerates indicate rhyolite was exposed nearby in the source region for the deposits.

Xbg **Biotite-quartz gneiss (Early Proterozoic)**—Biotite- and muscovite-biotite-quartz gneiss and garnet-biotite-quartz gneiss in northwest part of area. Locally has andalusite porphyroblasts as much as 7 mm long that are altered to sericite and minor amounts of chlorite, opaque mineral, garnet, tourmaline, and quartz. Micas formed under synkinematic and postkinematic conditions. Biotite partly chloritized in some rocks and completely chloritized in a few rocks. Grain size is generally 0.2-0.5 mm, except locally garnets are as much as 2 mm in diameter. Protoliths probably shaly siltstone and sandstone.

Xbc **Biotite-quartz schist (Early Proterozoic)**—Biotite-quartz schist, biotite-chlorite-quartz schist, biotite-chlorite-sericite-quartz phyllite, chlorite-sericite-plagioclase-quartz schist in northwest part of area. Contains some layers of biotite-sericite-epidote-quartz-magnetite phyllite and metachert. Gray to pale greenish-gray. In many rocks crystalization of biotite was later or continued longer than that of chlorite and lasted longer than deformation. Fine grain size (<0.2

mm) and composition suggests shale or mudstone protoliths. Contains some tuffaceous components, especially in southern part near contact with greenschist (Xgs). In northwest part of area.

Xgs **Greenschist (Early Proterozoic)**—Greenish-gray, and green greenschist and greenstone and green, pale greenish gray, and gray phyllite consisting of albite-actinolite-epidote schist, epidote-albite-tremolite phyllite, sericite-epidote-chlorite phyllite, and chlorite-epidote-actinolite schist. Some rocks have fragmental textures. Contains rare layers of metarhyolite 3-4 m thick, pods and lenses of marble and dolomitic marble as much as 2 m thick, and layers of dolomitic sericite phyllite. Protolith probably mostly andesitic or basaltic lava flows and interflow crystal-lithic tuff, calcareous shale, and limestone. In the west-central part of the quadrangle unit includes layers of hornblende gabbro or diorite that are locally metamorphosed to greenschist. These layers are interpreted to be sills, but are not mapped separately because of their thinness, scattered distribution, and indistinct contacts . Unit contains sparse to numerous lenses and layers of metachert 1 cm to 5 m thick having various proportions of opaque minerals and ranging from gray to reddish brown and black and grading to iron formation. Siliceous layers are thicker and longer in the north central part of the area. Thicker layers of metachert or areas containing many thinner layers are mapped separately as the banded iron formation and metachert unit (Xbm).

Xrm **Metarhyolite and greenschist (Early Proterozoic)**—Sericite-quartz-feldspar phyllite containing layers of greenschist and lenses of metachert in north part of the area east of the Agua Fria River. Local fragmental texture. Southern part of unit also contains some calcareous phyllite and marble. Probable protolith is rhyolitic tuff and lesser amounts of andesitic volcanic and sedimentary material.

Xrmg **Rhyolite of Moore Gulch (Early Proterozoic)**—Nonbedded pale greenish gray, somewhat phyllitic rock containing subhedral to euhedral quartz crystals as much as 1 mm in diameter and a few euhedral to anhedral plagioclase grains. Locally contains quartz as much as 4 mm in diameter and pumice(?) fragments in matrix of sericite, chlorite, and very fine grained quartz and feldspar. North of Moore Gulch in Secs. 35 and 36, T. 8 N., R. 2 E.

Xgp **Greenschist and phyllite (Early Proterozoic)**—Greenschist, sericite-quartz phyllite, chlorite-sericite phyllite, chlorite-sericite-plagioclase phyllite and gneiss containing layers of well foliated sericite-quartz phyllite grading to granular phyllite resembling parts of sericite phyllite unit (Xsp); metarhyolite tuff and siliceous phyllite. Contains a few bodies of metagabbro, quartz veins and lenses, and ferruginous metachert lenses. Probably from andesitic tuffs and flows and fewer beds of more felsic tuff. Moore Gulch area in Sec. 37, T. 8 N., R. 2 E. and Sec. 31, T. 8 N., R. 3 E.

Xsp **Sericite phyllite (Early Proterozoic)**—Greenish gray to medium bluish gray sericite phyllite and chlorite-sericite phyllite. Mostly lacks bedding but locally grades from phyllite to a granular phyllite containing euhedral to anhedral quartz and feldspar grains as much as 1 mm in diameter. Contains quartz and quartz-carbonate veins, lenses, and stringers. Contains a few metachert lenses as much as 10 m long. Probably derived from felsic vitric and crystal-vitric tuff. Along Moore Gulch fault east of Moore Gulch and as an interbed or infold in greenschist and phyllite (Xgp).

Xpm **Phyllite, marble, and greenschist (Early Proterozoic)**—Gray, pale green, and pale greenish gray sericite phyllite, sericite-chlorite phyllite, chlorite-sericite-quartz phyllite, chlorite-carbonate-sericite-feldspar-quartz phyllite, calcareous sericite phyllite, calcareous chlorite-sericite phyllite, chlorite-quartz sericite marble, dolomitic sandy marble, marble, quartz-chlorite-plagioclase schist, and greenschist. Some rocks have a fragmental texture or contain anhedral to subhedral plagioclase or quartz and plagioclase grains and are interpreted to be tuffs or tuffaceous

sediments. Protoliths of this unit predominantly shale, calcareous shale, tuffaceous shale, and smaller amounts of felsic to mafic tuff, intermediate to mafic flows, and shaly or sandy dolomite and limestone. Contains lenses of metachert as much as 1 m thick having various amounts of opaque minerals.

Xpcs **Sericite and chlorite-sericite phyllite (Early Proterozoic)**—Pale gray, gray, pale greenish gray, and greenish gray sericite and chlorite-sericite phyllite and granular phyllite containing various proportions of anhedral to subhedral quartz and plagioclase grains as much as 1 mm in diameter and less abundant sericitic phyllite fragments as much as 5 mm long, which may be derived from pumice fragments. Locally biotite-bearing. Locally contains layers and lenses of greenschist 0.5-20 cm thick. Beds of phyllite and granular phyllite generally a meter to several meters thick. Upper contact is gradational with phyllite, marble, and greenschist (Xpm). Probably derived from dacitic and andesitic tuff and tuffaceous sediments. Resembles sericite phyllite (Xsp) but contains more andesitic material and is interpreted to be lower in the stratigraphic section. Cut by Moore Gulch fault zone on the east.

Xbm **Banded iron formation and metachert (Early Proterozoic)**—White, gray, reddish brown, and black siliceous rock. Largest continuous layers of iron formation and metachert are in northwest part of the area where they are as much as 360 m long and 20 m thick. The larger areas mapped as this unit are in the north central part of the area and consist of many lenses and layers of iron formation and metachert intercalated in the country rock, which consists of at least 50% of the rock in the areas mapped . Unmapped lenses as much as 2 m thick and 5-10 m long are widespread in mafic and intermediate metavolcanic and metasedimentary rock units (Xgs, Xgg, Xpm).

Xdg **Metadiorite, metagabbro, and greenschist (Early Proterozoic)**—Weakly foliated hornblende diorite or gabbro grading to greenschist and greenstone. The diorite and gabbro contains amphibole as much as 5 mm long altered to tremolite or actinolite, and interstitial sausseritized plagioclase. Locally the coarser grained rock appears to occur as sills in greenschist, but in many places the margins of the coarse grained rock are indistinct due to metamorphism. The metadiorite and metagabbro are more resistant to weathering than the well foliated, finer grained rock and dominate the colluvium on this unit, even though exposures in washes indicate that the coarser-grained rocks make up less than 50% of the unit. Sills of metadiorite and metagabbro occur outside the mapped unit, especially northeast of the unit.

Xu **Undifferentiated metavolcanic and metasedimentary rocks (Early Proterozoic)**—Shown only in cross section.

Introduction

The New River and Daisy Mountain 71/2' quadrangles lie at the northeastern margin of the southern Basin and Range province in Arizona and on the north fringe of the Phoenix metropolitan area. Detailed mapping was conducted in that area to obtain more detailed structural and stratigraphic information about the possible southwestern extension of the Moore Gulch fault zone (Maynard, 1989) and relations between it and adjacent Proterozoic metamorphic rocks. Anderson (1989) divided these rocks into three groups, oldest to youngest: the Black Canyon Group, the Union Hills Group, and the New River Mountain felsic complex. Since these groups and the relations between them have not yet been adequately defined in the literature to qualify for official acceptence as geologic names, here they will be called groups 1, 2 and 3 respectively.

When the Geologic Division of the U.S. Geological Survey was reorganized in 1995, fieldwork on this project was discontinued. However by that time most of the area where Proterozoic rocks are exposed in the two quadrangles had been mapped. A preliminary version of the New River quadrangle (Bryant, 1994) has been released. Here mapping in the western half of the Daisy Mountain quadrangle and a slightly modified version of the New River quadrangle are combined so that the map relations between rocks of the three Proterozoic groups and between them and the Moore Gulch fault zone and its possible southwestern extension can be viewed. Chemical data from some of the Proterozoic and Tertiary rocks and structural data from the Proterozoic rocks are summarized.

Geology

Proterozoic rocks

In the northern part of the area the Moore Gulch fault (Maynard, 1986, 1989) separates group 3 rocks on the east from group 1 rocks on the west (Anderson, 1989). The Moore Gulch fault has been considered a major tectonic boundary separating the Yavapai and Mazatzal provinces (Karlstrom and Bowring (1988), a less profound feature separating tectonic blocks (Karlstrom and others, 1987), or a zone of high strain that dies out to the southwest (Anderson, 1989; DeWitt, 1991; Karlstrom and Williams, 1998).

The Moore Gulch fault extends from the northern edge of the New River area northeastward for 50 km, and southwest for 1.5 km where it is covered by Tertiary rocks for a distance of 7 km. To the southwest rocks along the projection of the fault are intermittently exposed for about 3 km, but beyond they are largely covered by Tertiary and Quaternary deposits. At the north edge of the area, the fault separates a mass of rhyolite and granite, which forms the New River Mountains to the east, from metavolcanic and metasedimentary rocks on the west that strike into the fault at an angle of about 10°. Northwest of the community of New River sericite and chlorite-sericite phyllite (Xpcs) in group 1 rocks strikes N 70° E into the N 40° E-trending Moore Gulch fault and the high-silica rhyolite of group 3 (Xrh). The fault is concealed by alluvium along the New River. Facing directions of the metavolcanic and metasedimentary rocks in group 1 west of the Moore Gulch fault are not known. The stratigraphic sequence is inferred to face northwest based on observations and interpretations in areas to the southwest and north (Darrach and others, 1991; Burr, 1991).

The rhyolites of group 3 have been correlated with the 1,700 Ma-Red Rock Group (Conway and others, 1987). The rhyolites and granites were called the New River felsic complex and correlated with the Verde River batholith by Anderson (1989). Maynard (1989) called these rocks and associated metasediemntary rocks the New River Group.

Karlstrom and Bowring (1988) assigned group 1 rocks northwest of the Moore Gulch fault to the Ash Creek block. In the northern part of the Ash Creek block volcanic rocks are 1.74 Ga and were deformed before intrusion of the 1.735-Ga Cherry batholith (Karlstrom and Bowring, 1993). Farther south

in the Ash Creek block, near the New River area, no such information is available, and the complex stratigraphy does not allow correlation between the dated units and the rocks in this area. The metavolcanic and metasedimentary rocks west of the Moore Gulch fault are intruded by the 1.72- Ga quartz diorite of Bland (DeWitt, 1991: Bowring and Karlstrom, 1986). Anderson (1989) called the rocks in this block, except for the northern end, the Black Canyon Creek Group, and he extended that unit into the New River area northwest of the Moore Gulch fault. Maynard (1989) called the rocks in group 1 near the Moore Gulch fault the Moore Gulch Group.

The Shylock fault zone forms the west edge of the Ash Creek block. The Shylock fault has been mapped 30 to 80 km north of the New River quadrangle (Anderson and Creasey, 1967; Anderson and Blacet, 1972b), and has a minimum of 8 km of right lateral offset (Anderson and Blacet, 1972a). According to Anderson (1989), stratigraphic markers can be mapped through the highly strained rocks of the Shylock zone and it is a zone of high strain rather than a major discontinuity along a fault. In generalized regional compilations the zone has been extended south and southwest so that it projects through the northwest corner of the New River area (Karlstrom and others, 1987). Karlstrom and Bowring (1988) interpreted it to be a terrane boundary. Detailed study of the zone about 30 km north of the New River area revealed that both shortening and left lateral strike-slip motion have occurred along it, but no amounts of offset are given (Darrach and others, 1991). The Shylock zone is within a west-facing stratigraphic sequence composed of bimodal metavolcanic rocks unconformably overlain by discontinuous mafic metavolcanic rocks and by graywacke and pelitic schist (Darrach and others, 1991). The two volcanic rock units are in the Black Canyon Creek Group of Anderson (1989), who placed an unconformity at the base of the metasedimentary rocks, which he named the Cleator Formation.

In the New River area the biotite-quartz gneiss (Xbg) in the northwest corner of the quadrangle may correlate with the metasedimentary rocks in and adjacent to the Shylock zone to the north. However, the contact between metasedimentary rock and greenschist to the southeast appears to be gradational rather than abrupt, although exposures are not continuous.

About 20 km WSW from the southwest corner of the map area, metasedimentary rocks overlie iron formation and metavolcanic rocks and form a north- to northwest-facing stratigraphic sequence. A zone of ductile deformation and retrogressive metamorphism is interpreted to be the southwest extension of the Shylock fault zone. Kinematic indicators show that the northwest side went up, but no significant displacement occurred after the height of regional metamorphism (Burr, 1991).

West of the Moore Gulch fault zone in the north part of the area two relatively distinct units, the metarhyolite of Moore Gulch (Xrmg) and the phyllite-slate unit (Xsp), are covered to the south and were not recognized 4 km along strike where Proterozic rocks are again exposed and are predominately greenschist. Farther southwest the metavolcanic rocks interfinger with and grade into a stratigraphic section containing much metasedimentary rock (Xpm). The sericite and chlorite-sericite phyllite (Xpcs) unit west of New River resembles the sericite phyllite unit (Xsp) at Moore Gulch, but the former is more thinly bedded and contains more andesitic material.

On Daisy Mountain in the southeastern part of the map area group 2 rocks, a sequence of metaandesitic flows and tuffs and metagraywacke (Xgg and Xgr), dip and face north (Reynolds and DeWitt, 1991). Anderson (1989) called these rocks part of the Union Hills Group, and he placed them stratgraphically between his Black Canyon Group and the younger New River Felsic Complex. As yet rocks of this sequence have not been directly dated. In the map area the contact between these rocks and the younger slate, phyllitic slate and graywacke (Xps) of group 3 to the north is concealed by Tertiary basalt on the north and by Quaternary and Tertiary gravel on the west. That contact may be an unconformity, or a fault as shown by Anderson (1989). I favor the interpretation that it is an unconformity because of the interpretation, discussed below, that the phyllitic slate, slate, and graywacke (Xps) of group 3 stratigraphically underlie the rhyolites (Xrh, Xrl) and are the oldest rocks in group 3 exposed in this area.

According to Anderson (1989) the Moore Gulch fault zone dies out into a zone of high strain in the southern part of the map area, and the succession of rock types there represents a normal stratigraphic

section. If the rocks in the northwestern part of the map area face northwest, as extrapolations from areas to the north and southwest suggest, facing direction must reverse to form a normal stratigraphic section in the central part of the New River area? All the Proterozoic rocks between the New River in the southeast and map unit biotite-quartz gneiss (Xbg) in the northwest corner of the area are highly strained, as Anderson (1989) observed. There are no persistent lithologic marker horizons that might allow the determination of a major fold and accompanying reversal of facing direction needed to produce a southeast-facing section in the central part of the area. Evidence from map pattern and detailed field observations indicate that, east of the Moore Gulch fault zone, the high-silica rhyolite (Xrh) adjacent to the fault is in the upper part of group 3 rather than at its base. That relation argues against the rhyolite simply being unconformable above group 1 rocks in the south-central part of the area. The question of whether the Moore Gulch fault zone dies out in the New River area depends very much on the interpretation of the stratigraphic relations between the various map units.

Attempts to determine stratigraphic relations by finding primary structures and textures were not successful in group 1 rocks. In some places where such features have been found, isoclinal folds producing a reversal of facing directions in distances of a meter or two have also been found. Units with well-defined contacts are scarce; many of the units mapped are distinguished entirely by differing proportions of the same rock types. Marker layers within the map units that might furnish a clue to the stratigraphy and structure of the group 1 rocks were not found. Bedding attitudes in area 3 (see below) generally dip steeply northwest, and most of the facing directions determined indicate tops to the northwest, but most of the bedding measurements were recorded at exposures lacking criteria for facing direction. The stratigraphic relations of the Proterozoic units shown on the correlation of map units are based on facing directions obtained in other areas and interpretations of relations between the major groups of rocks by the workers mentioned above. Given the uncertainties inherent in the above criteria, additional structural and/or stratigraphic relations need to be determined in this area or nearby to improve the understanding of the local Early Proterozoic stratigraphic and structural framework.

In the phyllitic slate, slate, and graywacke (Xps) graded bedding or channeling in many outcrops give stratigraphic facing directions. The rocks in this unit are highly deformed and contain many minor folds of diverse plunge. Low silica rhyolite (Xrl) stratigraphically overlies the shale and graywacke unit. In a volcaniclastic unit directly overlying the shale and graywacke, fragments of reddish brown shale are mixed with fragments of low silica rhyolite in the northeastern part of Sec. 7, the northwestern part of Sec. 8, and the eastern part of Sec. 5, T. 7 N., R. 3 E. The intersection of the contact with topography suggests that the contact is low- to moderate-dipping and deformed by minor folds in these areas. The attitude of the planes of pumice flattening in the high silica rhyolite (Xrh) indicate that it physically overlies the shale and graywacke unit and the low silica rhyolite in Sec. 32, T 8 N., R. 3 E. and secs. 5, 7, and 18, T. 7 N., R. 3 E.. Map relations north of the New River indicate that the base of the high-silica rhyolite dips about 25° to the west. Bedding attitudes and facing directions in the slate and graywacke unit directly below the high silica rhyolite in secs. 32, 5 and 6, T. 8 N., R. 3 E. are sparse. Along the New River in Sec. 5, T. 7 N., R. 3 E. bedding in the phyllitic slate, slate, and graywacke unit dips steeply east or is overturned consistently in rather continuous exposures suggesting a discontinuity between at least the internal structure of the phyllitic slate, slate and graywacke unit and the moderate to gently northwest-dipping contact between that unit and the overlying high silica rhyolite. This discontinuity formed before the cleavage that cuts both the slate and graywacke unit and the adjacent rhyolites. Overall the minor structures in the phyllitic slate, slate, and graywacke unit are much more complex than those detected in the massive, competent rhyolites. Ductility contrasts are great between those units. The contrast suggests that the slates may have been deformed once before the deposition of the rhyolites and is there an unconformity between the slates and the rhyolites.

Along the contact between the high- and low-silica rhyolites in many places in Secs. 7 and 18, T. 7 N., R. 3 E. is 1-2 m of grayish red to purplish gray, and gray phyllitic slate, slate, and argillite this shale could be either a slice along a pre-metamorphic fault between the two rhyolite units or thin bed between the

two rhyolite units. If the former, a premetamorphic fault extends along the high-silica rhyolite (Xrh)-phyllitic slate, slate, and graywacke (Xps) contact throughout the area. Alternatively the thin slate between the two kinds of rhyolite could simply be a bed deposited between the eruptions of the two rhyolites.

I interpret the map relations to indicate that the slate and graywacke unit (Xps) underlies the rhyolites and that the slate and graywacke unit in the northeastern part of the map area occurs in a northeast-trending doubly plunging anticline. The contacts between the rock units have gentle to moderate dips in many places, in contrast to the interpretation of Maynard (1989) that the units are subvertical beds with the high silica rhyolite at the base and the low silica rhyolite at the top. The high-silica rhyolite overlies the low silica rhyolite in secs 7 and 18, T. 7 N., R. 3 E. Intrusion of aplite and leucocratic granite (Xag) into low-silica rhyolite in the northeastern corner of the map area also supports the interpretation that the low-silica rhyolite is older than the high-silica rhyolite.

Structural Geology

The Moore Gulch fault is the most important structure in the quadrangle. It separates the rocks of Group 1 on the west, which have been interpreted to be west-facing, from rocks of group 3 on the east, which I interpret to also face west near the fault. The fault crops out rarely in the map area. Just north of the map area in a tributary gulch east of Moore Gulch the fault is exposed. It trends N25°E and is about vertical. The foliation in the sericite phyllite (Xsp) to the west trends into the fault plane. Rocks exposed near or adjacent to the fault in the northern part of the area are generally ductilely deformed. Brittle deformation effects are minor or absent. The rocks west of the fault contain a few granite dikes similar to ones in slate, phyllitic slate, and graywacke of group 3 northeast of New River and in group 1 rocks west of there. These dikes are mylonitic gneisses due to ductile deformation.

West of the settlement of New River bedding and foliation in the sericite and chlorite sericite phyllite (Xpcs) trend about N 60°E into the concealed contact with the high-silica rhyolite (Xrh) of group 3 along the Moore Gulch fault, which trends about N 40°E here. In a roadcut in the north bound lanes of highway I-12 in the east central part of Sec. 22, T. 7 W., R. 2 E., bedding and foliation in the sericite and chlorite-sericite phyllite unit trend N 65-85°E, dip 65°S to vertical, and are commonly parallel. In places bedding is cut by a different foliation trending N35-45°E and dipping 60-65° northwest. That foliation is interpreted to be younger than the bedding-parallel foliation and to have formed during deformation along the Moore Gulch fault.

Maynard (1989) concluded that the Moore Gulch fault was reactivated in late Tertiary time because it cuts the Miocene trachyandesite flow and lahar (Ta) 0.5-1 km north of this map area. On a review of that area, I could not find contacts that were sufficiently controlled by outcrops to prove this interpretation.

Given the current understanding of the stratigraphy of the groups 1 and 3 rocks described above, I conclude that the Moore Gulch fault continues south through the Proterozoic rocks to the southern part of the map area. Most of the movement on the fault was by ductile deformation under greenschist facies conditions. These conclusions basically agree with those of Anderson (1989), DeWitt (1991) and Karlstrom and Williams (1998).

To further analyze the structure of the Proterozoic rocks the map was divided into six areas mostly parallel to the N 40° E-trending Moore Gulch fault zone from northwest to east (fig. 1) to determine whether structures differ across the fault zone, between the groups of Proterozoic units, or with distance from the fault. Areas either side of the fault zone are about 3 km wide and parallel with it. Area 1 in the northwestern corner of the quadrangle is about 6 km wide because few Proterozoic rocks are exposed in that part of the map area. Areas 1-3 are underlain by the group 1 rocks, which are interpreted to be the oldest. The N 40°E-trending Moore Gulch fault and its southward projection along the northwest contact of

the high-silica rhyolite (Xrh) form the boundaries between areas 3 and 4. Area 4 is underlain by the group 3 rocks, which are interpreted to be the youngest (Xps, Xrl, Xrh). Area 5 is underlain by phyllitic slate, slate, and graywacke (Xps) of group 3. Area 6 is underlain by greenschist, and phyllite (Xgg) and graywacke, conglomerate, greenschist, and phyllite (Xgr) of group 2, which are interpreted to be of intermediate age.

Foliation strike in area 1 has two maxima (fig. 2A). The less prominent one is N 35°E and perhaps parallel with Shylock fault or shear zone which may pass through the area but was not recognized in mapping. The other is N 50° E similar to the maxima in areas 2 and 3. These foliation maxima have a vertical dip, but dips range down to less than 60°. In areas 2 and 3 west of the Moore Gulch fault zone foliation strikes N 50°-55° E and dips steeply to the northwest (figs. 2B,C). In area 4, which is underlain by younger Proterozoic units of group 3, the foliation strikes N35°E parallel the Moore Gulch fault and dips 75° southeast (fig.2D). That foliation is most intense and pervasive within a kilometer of the Moore Gulch fault. Foliation data from area 5 (fig. 2E) trend N 70° E and dip moderately to steeply northwest and steeply to the south and the southeast They can be interpreted to lie along a girdle, whose axis trends N 75°W and plunges 54° SW. Foliation in area 6 trends N 70° E and dips almost vertically (fig. 2F). That trend is similar to area 5 but distinctly more easterly than that in the other areas. The foliation maxima in areas 3, 4, 5, and 6 are streaked out, possibly due to rotation about steeply plunging axes.

Streaking and lineation formed by stretched mineral grains plunge steeply everywhere. In area 1 the lineation maximum is about vertical, but some plunges are steep to the northwest or southeast (fig. 3A). In area 2 the maximum of the plunge of the lineation is 85° W (fig. 3B). The lineation in area 3 has maxima at N 65° W plunging 65° NW and N 45° W plunging 80° NW (fig. 3 C). In area 4 east of the Moore Gulch fault the lineation maximum plunges 80° S 35° E (fig 3D). The rocks in area 5 lack lineation. In area 6 the lineation maximum trends S 70 ° W and plunges 85° SW (fig. 3E). Except in area 6, the lineation maxima are smeared out in a northwest-southeast direction suggesting that they may have been gently folded along axes trending northeast and plunging nearly horizontal (fig. 3A,B,C,D). A similar effect on the distribution of the poles to foliation and cleavage (fig. 2) is not detectable (fig. 2). The smeared out pattern in the lineation diagrams is probably related to its relatively constant azimuth on foliation planes having a 90° degree range in strike.

Bedding attitudes in areas 1 and 2 are too sparse to treat statistically. In area 3 (fig. 4A), the statistical bedding plane trends N 66°and dips 75° NW, and the maximum in the distribution of bedding attitudes is N 75° E dipping 82° NW. A pole to the girdle fitted to the bedding data in area 3 plunges steeply to the northwest, an attitude similar to that of one of the of the lineation maxima (fig 3C). The relatively small number of bedding measurements in area 5 can be related to a girdle whose axis trends N12°W and plunges 63° SE (fig. 4E). In area 6 the bedding maximum (fig 4F) trends N 80°E and dips 80° NW. A girdle with an axis trending N 52° E and plunging 66° NE can be fitted through the distribution pattern of the bedding. That axis differs from the lineation maximum, which plunges W at 85° (fig 3E).

In area 4 the rocks contain more bedding information than elsewhere. Siltstone and sandstone beds are widespread in the phyllitic slate unit (Xps). The rhyolite tuffs (Xrh, Xrl) have flattened pumice fragments that are interpreted to represent bedding. The maximum for the bedding distribution is the N 40° E, 80° SE, which is similar to the maximum for the foliation and cleavage, but there is a significant scatter (fig. 4B). Possible causes of the scatter are folding around axes trending N45°E plunging 9°NE and trending N31°W and plunging 87° SE.

Bedding attitudes of the phyllitic slate, slate, and graywacke (Xps) and the low-and high-silica rhyolites (Xrl and Xrh) in area 4 are different (fig 4C,D). The bedding in the phyllitic slate, slate, and graywacke (Xps) strikes N 42°E and dips about 78° SE (fig 4C), a maximum similar to that of all the bedding in area 4. The statistical plane of all the bedding measured in area 4 strikes N 52° w and dips 85° SE. Plunges of minor folds in the phyllitic slate, shale, and have a prominent maxima at N 55°E plunging

77° NE and a smaller one plunging 61° S 55° W and scattered more gentle plunges in various directions (fig. 5B). These fold axes lie in the statistical bedding plane (fig 4C) at an angle of 64° to each other. Their axial planes have a maximum at N 80°E dipping 80°SE, but they are distributed in a girdle around a steeply plunging axis (fig 5C). These minor fold axes do not appear to be related to the streaking lineation (fig. 3D) and are probably older. The minor folds have no clear relation to any major folds one might infer from the map patterns or the compilation of bedding attitudes. Field relations suggest that the history of these minor folds is complex. In a wash in the southeast half of Sec. 5, T. 7 N., R. 3 E. are folds having a bewildering array of orientations. In one exposure the axis of a minor fold is isoclinally folded. In another an isoclinal fold is folded by an open fold.

The bedding in the rhyolites has a statistical maximum at N 72°E dipping 21° NW, which might be interpreted as due to folding around an axis trending N 18°E and plunging 4° NE (fig 4D). The statistical distribution of bedding attitudes suggests that those rocks are in folds having long north to northwesterly gently dipping limbs and shorter vertical limbs. The numerous gentle dips measured in the volcanic rocks support the interpretation that they lie in open folds which, combined with the map data, indicate that they overlie the phyllitic slate, slate, and graywacke. The juxtaposition of the two fold patterns suggests that the phyllitic slate, slate, and graywacke were deformed before the volcanic rocks were emplaced and that there is an unconformity between the two units. Alternatively, the difference in fold patterns between the two units might be due to a major difference in ductility between the two units.

The foliation and lineation in area 4 along the Moore Gulch fault zone appears to be related to ductile deformation in which maximum shortening (ε_3) was NW-SE and maximum extension (ε_1) was essentially vertical. However a similar pattern of deformation affected the other rocks of the New River region, but ε_3 had a more northerly trend than in the Moore Gulch fault zone and that deformation was somewhat earlier. In the northern part of area 1 the steep foliation trends parallel to the Shylock shear zone inferred to pass through that region. These structures are younger than the rhyolites east of the Moore Gulch fault zone inferred to be about 1.7 Ga.

The New River area is at the margin of the Basin and Range province. In the southwestern part of the area numerous normal faults many of northwest or north strike and some of other strikes break the Tertiary sedimentary and volcanic rocks through the 15 Ma New River Mesa Basalt of Gomez (1979) (Tnb). Most of the faults do not displace the younger Miocene rocks in the basin along the Agua Fria River. Displacement on each fault is generally 100 m or less, but locally as much as 150 m, and the blocks are rotated down to the northeast. (Sec. D-D'). Probably more faults than are shown are concealed beneath Quaternary or latest Tertiary deposits or not detected in the Proterozoic rocks. The unconformity between the New River Mesa Basalt of Gomez (1979) and the older Miocene and Oligocene rocks indicates that some of the Miocene deformation was before extrusion of the basalt.

Metamorphism

Rocks in most of the area are metamorphosed at conditions of the greenschist facies. Mafic metavolcanics contain chlorite, actinolite or tremolite, epidote, and albite and felsic rocks have sericite and chlorite. A few rocks in all groups contain some metamorphic biotite.

In the northwest corner of the area the metamorphic grade is higher. In the northern part of Sec 3, T. 7 N., R. 1 E. biotite commonly accompanied by chlorite is a major constituent in most of the rocks, which are biotite-chlorite and sericite-biotite-chlorite schist and phyllite. Generally the chlorite formed synkinematically, where the biotite formed synkinematically and post kinematically. In some rocks the biotite is entirely postkinematic and forms small porpyroblasts as much as 0.5 mm long.

In the extreme northwest corner of the map area in Sec. 34, T.8 N., R. 1 E. the rocks contain garnet and sericite rich areas that probably represent former andalusite porphyroblasts. Biotite and, less commonly, garnet are partly altered to chlorite. The higher metamorphic grade in this part of the area is due

to proximity to the contact of the Crazy Basin Quartz Monzonite (monzogranite) 1 km to the northwest. An U-Pb zircon date of 1699±5 Ma (Conway and others, 1987) has been obtained from this pluton, and that is the approximate age of the medium grade metamorphism, a conclusion also reached by Burr (1991) to the southwest and Darrach and others (1991) to the north of the New River area. Strong strain and vertical extension accompanied greenschist facies metamorphism of group 1 rocks west of the Moore Gulch fault and of group 3 rocks east of the fault. The latter are probably correlative with the Red Rocks Group emplaced 1,700±6 Ma (Silver and others, 1986). These relations indicate that the main structural and metamorphic features preserved in these rocks formed at about 1,700 Ma.

The rhyolitic rocks, slate, and graywacke east of the Moore Gulch fault and its projection and north of the greenschist, greenstone, and phyllite (Xgg) and graywacke, conglomerate, greenschist, and siltstone (Xgr) are overall less severely strained than the rocks of the older sequences. They are highly strained adjacent to and east of the Moore Gulch fault zone. East of the fault high strain is concentrated in somewhat discontinuous zones of highly foliated rock, which Maynard (1989) mapped as faults. Farther east in area 4 in many places steeply dipping tectonic foliation is overprints a variously dipping compaction foliation formed by flattened pumice fragments in a thick sequence of ash flow tuffs. In area 5 the granite and rhyolite lack foliation and lineation, and the phyllite and graywacke lacks lineation, although it is ductilely folded and has cleavage.

The greenschist, greenstone, and phyllite (Xgg) and graywacke, conglomerate, greenschist, and siltstone (Xgr) are less strongly strained than the rocks northwest of the Moore Gulch fault zone and its projection. Primary textures and structures, such as graded bedding, amygdules, and porphyritic textures in sedimentary and volcanic rocks are preserved in many outcrops, and some of the metavolcanic rocks lack cleavage.

Chemistry of the Proterozoic metavolcanic rocks

The content of major and some minor elements of the Proterozoic metavolcanic rocks helps identify their protoliths and shows differences between the major groups. The volcanic rocks of at least the older two groups were probably deposited subaequously and could have been altered by interaction with water, probably seawater, before they were metamorphosed. The rocks look altered adjacent to masses of iron formation and metachert. Such obviously altered rocks were not analyzed. However, alkali contents may be changed by interaction with seawater without producing megascopically visible effects. Contents of some rare earths may be changed during regional metamorphism, so rare earths were not analyzed.

Table 1. Chemical analyses of Proterozoic metavolcanic rocks. Determined by X-ray spectroscopy; major elements by D.F. Siems and J.S. Mee; minor elements by J. Kent. U and Th by DNAA by R.J. Knight, U.S. Geological Survey, 1995.

Sequence	1	1	1	1	1	2	2	2	2	3	3	3	3	3	3
Map unit	Xgs	Xgs	Xgs	Xgs	Xrmg	Xgg	Xgg	Xgg	Xgg	Xrl	Xrl	Xrh	Xfi	Xrh	Xp
Field no.	NR-21	NR-353	NR-60	NR-142	NR-834	NR-267	NR-271	NR-932	NR-992	NR-746	NR-744-c	NR-871	NR-598-a	NR-560-a	NR-866
Lab. no.	D-561965	D-561970	D-561966	D-561967	D-561975	D-561968	D-561969	D-561978	D-561980	D-561974	D-561973	D-561978	D-561972	D-561971	D-561977
Concentration in weight percent															
SiO_2	45.70	48.30	48.40	51.50	75.40	48.40	50.00	58.20	74.90	63.00	68.5	74.10	75.00	75.40	52.20
Al_2O_3	14.50	13.10	12.30	18.70	12.00	19.70	20.00	15.10	12.40	14.80	14.4	13.40	13.60	13.30	15.10
$FeTO_3$	13.50	14.50	10.00	9.40	2.43	9.20	8.86	7.29	1.59	6.47	3.75	2.33	2.33	2.01	10.20
MgO	7.78	6.66	11.50	3.80	0.78	4.70	4.26	3.19	0.30	1.37	0.92	0.35	0.48	0.26	3.92
CaO	13.00	10.20	9.31	2.38	1.08	9.92	5.67	6.42	1.86	3.88	1.51	0.11	0.14	0.11	8.00
Na_2O	0.91	2.71	1.55	5.17	5.06	2.47	4.70	2.14	2.83	3.63	4.72	2.28	4.38	1.40	2.39
K_2O	0.11	0.08	0.53	3.16	0.52	0.17	0.38	1.93	2.03	2.90	2.81	4.30	1.49	4.42	0.42
TiO_2	0.65	1.54	0.45	1.35	0.23	0.47	0.54	0.47	0.14	0.92	0.62	0.39	0.29	0.34	1.03
P_2O_5	0.09	0.15	0.06	0.17	0.06	0.15	0.23	0.17	0.05	0.38	0.16	0.08	0.09	0.08	0.32
MnO	0.20	0.16	0.16	0.16	0.02	0.14	0.12	0.14	0.03	0.14	0.08	0.08	0.02	0.07	0.21
LOI	2.70	1.08	4.80	3.30	1.69	3.78	4.30	4.10	2.77	1.29	1.56	1.58	1.18	1.44	5.50
Total	99.14	99.48	99.06	99.09	99.27	99.10	99.26	99.15	98.86	98.78	99.03	99.00	99.00	98.83	99.29
Concentration in parts per million															
Th	0.80	0.80	0.80	0.80	4.10	1.40	2.70	5.73	11.20	6.31	10.2	11.40	11.50	12.30	4.27
U	0.08	0.16	0.13	0.32	2.36	0.57	0.93	2.73	4.22	3.61	4.55	3.34	3.01	5.13	2.02
Nb	10	10	10	10	10	10	10	10	13	12	14	16	13	17	10
Rb	12	12	18	43	10	10	13	53	50	66	72	126	66	126	20
Sr	194	144	188	148	90	500	410	480	88	305	235	66	85	36.	470
Zr	38	83	30	92	110	46	60	114	144	235	280	300	205	290	122
Y	23	23	13	26	30	10	16	18	25	50	46	60	36	57	22
Ba	31	30	138	1,300	194	136	90	890	570	840	1,050	1,300	435	1,200	205
Ce	30	30	30	30	42	30	37	43	90	102	112	136	102	116	50
La	30	30	30	30	30	30	30	30	54	54	45	64	50	68	30
Cu	146	102	38	66	10	88	140	90	26	10	10	10	87	10	53
Ni	110	85	265	63	10	40	34	18	10	10	10	10	10	10	34
Zn	86	73	70	106	12	71	90	58	16	110	62	84	134	77	95
Cr	186	122	930	104	20	102	45	102	20	20	20	20	20	20	68
Recalculated to 100 percent volatile free															
SiO_2	47.39	49.09	51.35	53.76	77.27	50.78	52.65	61.23	77.95	64.62	70.28	76.06	76.37	77.42	55.66
Al_2O_3	15.04	13.31	13.05	19.52	12.30	20.66	21.06	15.89	12.90	15.18	14.77	13.76	13.85	13.66	16.10
$FeTO_3$	14.00	14.74	10.61	9.81	2.49	9.65	9.33	7.67	1.65	6.64	3.85	2.39	2.37	2.06	10.88
MgO	8.07	6.77	12.20	3.97	0.80	4.93	4.49	3.36	0.31	1.41	0.94	0.36	0.49	0.27	4.18
Ca0	13.48	10.37	9.88	2.48	1.11	10.40	5.97	6.75	1.94	3.98	1.55	0.11	0.14	0.11	8.52
Na_2O	0.94	2.75	1.64	5.40	5.19	2.59	4.95	2.25	2.95	3.72	4.64	2.34	4.46	1.44	2.55
K_2O	0.11	0.08	0.56	3.30	0.53	0.18	0.40	2.03	2.11	2.97	2.88	4.41	1.52	4.54	0.45
TiO_2	0.67	1.57	0.48	1.41	0.24	0.49	0.57	0.49	0.15	0.94	0.64	0.40	0.30	0.35	1.10
P_2O_5	0.09	0.15	0.06	0.18	0.06	0.16	0.24	0.18	0.05	0.39	0.16	0.08	0.09	0.08	0.34
MnO	0.21	0.16	0.17	0.17	0.02	0.15	0.13	0.15	0.03	0.14	0.08	0.08	0.02	0.07	0.22
Na_2O+K_2O	1.05	2.83	2.20	8.70	0.77	2.77	5.35	4.28	5.06	6.69	7.52	6.75	5.98	5.98	3.00

Location and description of analyzed (Table 1) samples:

NR-21. Greenstone containing zones of foliation. Outcrop in wash just east of pipeline near south edge Sec 3, T. 7 N., R. 2 E. New River quadrangle, Maricopa County. 33°58'22"; 112°08'16". Laths of altered plagioclase as much as 0.3 mm long. Rock composed of epidote and tremolite and accessory quartz, sphene, chlorite, and opaque mineral.

NR-353. Outcrop of greenschist cut by calcite veinlets on the north side of the Aqua Fria River , NW1/4 Sec. 23, T. 7 N., R.1 E., New River quadrangle. Maricopa County. 33°56'27", 112°14'08". Anhedral to subhedral actinolite as much as 0.4 mm in diameter. One larger area of actinolite forms pseudomorphs after 1.5 mm long hornblende(?). Epidote 0.2-0.4 mm in diameter, euhedral albite as much as 0.4 mm long, and lenticular masses of very fine grained minerals may represent altered FeTi oxides.

NR-60. Outcrop in wash at the corner of Secs. 15,16, 21, and 22, T. 7 N., R. 2 E.. New River quadrangle. Maricopa County. 33°56'37"; 112°09'07". Pale green nonbedded phyllite containing lenses of quartz. Synkinematic tremolite as much as 0.6 mm long, albite, epidote as much as 0.05 mm in diameter, and accessory quartz and opaque minerals.

NR-142. greenish-gray well-foliated plagioclase porphyroid.. Outcrop in wash SE of center of Sec. 8, T. 7 N., R. 2 E.. New River quadrangle, Maricopa County. 33°57'41"., 112°10'19". Fractured and strung out grains of plagioclase a as much as 3 mm long altered to albite in a very fine grained matrix.

NR-834. Outcrop of nonlayered phyllitic rock containing euhedral quartz phenocrysts as much as 1 mm in diameter on the north side of Moore Gulch. NW1/4 Sec. 36, T. 8 N., R. 2 E.. Daisy Mountain quadrangle. Maricopa County. 33°59'55", 112°06'53". Euhedral phenocrysts of quartz as much as 1 mm in diameter and of plagioclase as much as 1.5 mm long in a very fine grained quartz-feldspar matrix containing sericite and chlorite. Accessory carbonate, opaque mineral, apatite, and zircon.

NR-267. Medium grained greenstone containing plagioclase phenocrysts as much as 5 mm long. Outcrop from 2120 foot knob west of east boundary of quadrangle and N of S line of Sec. 2, T. 6 N., R. 2 E.. New River quadrangle. Maricopa County. 33°53'27", 112°07'38". Chlorite as pseudomorphs as much as 2.5 mm in diameter after amphibole or pyroxene, plagioclase as altered phenocrysts, epidote and accessory actinolite, carbonate, and opaque minerals.

NR-271. Greenish gray massive to weakly foliated vesicular and amygdaloidal greenstone containing plagioclase as much as 5 mm long. Calcite and chlorite fill amygdules. Outcrop from top of hill 2208 at E edge of quadrangle in Sec. 11, T 6 N., R. 2 E.. New River quadrangle. Maricopa County. 33°59'27", 112°04'14". Euhedral, locally broken, plagioclase phenocrysts altered to albite in a matrix of epidote, chlorite, sericite, albite, and carbonate. Acessory opaque mineral.

NR-932. Porphyritic greenstone from block in wash, SE1/4 Sec. 36, T. 7 N., R. 3 E.. Daisy Mountain quadrangle. Maricopa County. 33°54'20", 112°06'03". Plagioclase as altered phenocrysts as much as 2 mm long in a matrix of very fine grained feldspar, epidote, chlorite, and accessory apatite, sphene, and opaque mineral.

NR-992. Rhyolite from an outcrop of a sill or flow 5 m thick in SE 1/4 Sec. 2. T 6 N, R. 2 E. Daisy Mountain quadrangle. Maricopa County. 33°53'56", 112°07'08". Anhedral to subhedral quartz to 0.5 mm diameter and euhdral to subhedral altered plagioclase as much as 1.5 mm long in a matrix of very fine grained sericite, quartz, feldspar, and quartz, and accessory chlorite, carbonate, opaque mineral, and zircon.

NR-746. "Dacite" containing phenocrysts of altered feldspar 3.4 mm long in a devitrified glassy matrix. Outcrop on North Canyon Creek WSW of center Sec. 4, T. 7 N., R. 2 E.. Daisy Mountain quadrangle. Maricopa County. 33°58'46", 112°03'30". Euhedral phenocrysts of sausseritized

plagioclase as much as 3.5 mm long in a microcrystalline matrix. Acessory opaque mineral, epidote, chlorite, and carbonate.

NR-744-c. Dark gray rock containing sausseritized phenocrysts of plagioclase as much as 4 mm long. Outcrop on west side of North Canyon near its mouth. SW1/4 Sec . 4, T. 7 N., R. 3 E.. Daisy Mountain quadrangle. Maricopa County. 33°58'38", 112°03'32". Plagioclase phenocrysts in a microcrystalline matrix, locally having flow or compaction structure. Accessory epidote, chlorite, quartz, opaque mineral, and zircon. Chlorite, epidote and opaque mineral form pseudomorphs after hornblende(?) phenocrysts as much as 1.3 mm long.

NR-871. Rhyolite welded tuff from outcrop on SE side of North Mountain in SE1/4 Sec. 32, T. 8 N., R. 3 E.. Daisy Mountain quadrangle. Maricopa County. 33°59'27", 112°04'14". Plagioclase phenocrysts as much as 1.7 mm long, potassic feldspar(?), quartz, sericite, and opaque mineral. Lithic fragments as much as 3 mm long.

NR-598-a. Metagranitic rock cut by veins and pods of quartz 0.5-20 cm thick in gray and purplish gray slate. From prospect pit in NE1/4,NE1/4 Sec 26, T. 7 N, R. 2 E.. Daisy Mountain quadrangle. Maricopa County. 33°55'39, 112°07'05". Euhdreal to subhedral quartz as much as 1.5 mm in diameter, euhedral plagioclase as much as 2.5 mm long and as 0.6 mm long laths in matrix. Potassic feldspar as much as 2 mm in diameter, sericite, and accessory chlorite, zircon , and opaque mineral.

NR-560-a. Pale greenish gray metarhyolite tuff from outcrop in wash in NE1/4 Sec. 13, T 7 N., R. 2 E.. Daisy Mountain quadrangle. Maricopa County. 33°57'21", 112°06'20". Quartz as much as 0.3 mm in diameter, sericitized feldspar in aggregates possibly formed from glass fragments as much as 1 mm long. Accessory apatite, opaque mineral, and zircon. Layering formed by lenticular concentrations of quartz grains is folded and cut by cleavage. Some sericite concentrations are parallel the layering; some are parallel the cleavage.

NR-866. Massive chloritic rock from outcrop in SE corner Sec. 31, T. 8 N., R. 3 E., Daisy Mountain quadrangle, Maricopa County. 33°59'20", 112°04'57". Main phases are chlorite and calcite. Also contains feldspar, epidote, opaque mineral, and sphene. Texture suggests that this was a fine-grained, fragmental volcanic rock. Mineralogy indicates a high degree of alteration.

On an alkali-silica diagram (fig. 6A) most of the rocks in group 1 analyzed are basalts, except for sample NR-142, which has an anomalously high alkali content. Perhaps the rock was altered by fluids during cooling on the seafloor or during metamorphism. Group 2 rocks plot in the basaltic trachyandesite, basaltic andesite, and andesite fields. No samples of quartz-bearing metavolcanic rock from this group, except for the metarhyolite, were analysed. The two low-silica rhyolites of group 3 plot in the dacite and adjacent part of the rhyolite field. The high-silica rhyolites of group 3 and rhyolites of the other groups all plot in the rhyolite field. The highly altered volcanic rock from group 3 is a trachyandesite and probably has been subject to some alkali metasomatism during cooling or metamorphism.

If we use elements less mobile than the alkalis plotted on a SiO_2-Zr/TiO_2 diagram (fig. 6B) (Floyd and Winchester, 1978) to determine the protoliths of these metavolcanic rocks, group 1 rocks fall into the subalkaline basalt field, group 2 into the andesite field, the low-silica rhyolites in the rhyodacite/dacite field, the high-silica rhyolites from group 3 and the rhyolites from groups 1 and 2 in the rhyolite field. The altered andesite from group 3 falls in the andesite field.

On a Zr/SiO_2 diagram rocks of group 3 are much richer in zirconium than rocks of similar SiO2 in the other groups (fig 6C). Analyzed rhyolites in groups 1 and 2 have a Zr content of about 120 ppm, similar to that of andesite of Group 2, whereas the Zr content of group 3 rocks is 200-300 ppm.

Tertiary rocks

The lower part of the Tertiary section is composed of interlayered and intertonguing basalt, felsic tuff, and gravel, which Gomez (1979) and Leighty (1997) called the Chalk Canyon Formation. K-Ar dates of basalt in this unit in the region range from 26 to 17 Ma.(Scarborough and Wilt 1979; Shafiquallah and others, 1980). In this map area a date of 26.48±0.56 Ma was obtained from a basalt at the base of the section in Tule Wash in NE1/4 Sec. 10, T. 7 N., R. 1 E. (Scarborough and Wilt, 1979). A basalt at the top of a basal basalt sequence in the north-central part of Sec. 11, T. 7 N., R. 2 E. yielded a date of 20.5±1.3 Ma (Eberley and Stanley, 1978). Local unconformities within the section are common. The map pattern suggests that a major unit of tuff and conglomerate (Ttc) overlies the 20.5 Ma basalt. The thickness of this unit ranges from 0 to 100 m. In the northwest part of the area it is overlain by 80 m of basaltic rocks, and locally it forms the top of the older sequence. East of Sweat Peak the unit is missing. The Tertiary rocks apparently were deposited on irregular topography so that it is difficult to infer stratigraphic relations in detail from the map pattern. For instance, the area around the trachyandesite dome was a topographic high during deposition of the lower part of the Tertiary section. It is overlain by the major tuff. The basalt section to the west pinches out against it, and it is overlain by tuff and conglomerate, which itself is locally very thin.

A younger, distinctive basalt, the New River Mesa Basalt of Gomez (1979), forms a series of flows capping the high mesas and unconfomably overlies the lower sequence. This unit has been dated by K-Ar whole-rock methods east and south of the map area at 15.4-14.7 Ma (Scarborough and Wilt, 1979; Gomez, 1979; Jagiello, 1987). This unit correlates with the lower part of the Hickey Formation, a widespread unit in the Colorado Plateau transition zone (Gomez, 1979; Leighty, 1997). In the map area this basalt forms an excellent marker horizon and is older than much of the extensional deformation at the margin of the Basin and Range province in the southwestern part of the map area.

On the ridge between Moore Gulch and the New River a flow of the of New River Mesa Basalt of Gomez (1979) is interbedded with gravels containing numerous clasts of aplite and granite (Xag) derived from the east and deposited by an ancestral New River. In the western part of the area lacustrine limestone and associated siltstone, claystone, sandstone, and conglomerate are younger than most of the deformation of the New River Mesa Basalt of Gomez (1979). Basal deposits of the sequence (Tsc) adjacent to the steep slopes capped by the basalt contain boulders of that basalt. These relations indicate that an ancestral Aqua Fria River had eroded the landscape after faulting and titling of the New River Mesa Basalt of Gomez (1979) before deposition of this, as yet undated, lacustrine sequence.

Chemistry of the Tertiary igneous rocks

Major and minor element analyses of the Tertiary igneous rocks define their composition better than hand specimen or petrographic study can and allow some comparison with data from a regional study by Leighty (1997).

Table 2. Chemical analyses of Tertiary igneous rocks. Major elements determined by wavelength dispersive X-ray fluorescence by D.F. Siems and J.S. Mee. Minor elements determined by "short count" INAA by G. Wandless and by energy-dispersive XRF by J. Kent. All in the laboratories of the U.S. Geological Survey.

Unit	Tnb	Tnb	Tnb	Tb	Tb	Tb	Tb	Tb	Ta	Tbta	Tt	Tpt
Field #	NR-546	NR-624	NR-486	NR-541	NR-645	NR-628	NR-544	NR-625	NR-839	NR-461-b	NR-517-a	NR-592-a
Lab. No	D-529410	D-529411	D-529405	D-529407	D-529414	D-529413	D-529408	D-529412	D-561976	D-529404	D-529406	D-529410
Concentration in weight percent												
SiO_2	49.4	50.4	51.1	43.6	49.3	50.5	50.5	56.5	57.6	49.3	59.9	61.5
Al_2O_3	14.6	16.7	17.1	12.7	16.2	15.3	14.9	16.5	16.2	14.6	14.9	15.3
$FeTO_3$	11.7	9.42	9.30	13.4	8.77	7.30	8.58	7.49	5.82	5.94	4.83	4.65
MgO	8.40	7.55	6.83	8.82	8.33	9.19	9.78	4.67	3.75	4.82	3.17	1.83
CaO	10.1	9.53	9.57	9.00	8.77	8.50	7.97	6.80	6.00	8.58	5.22	4.55
Na_2O	2.87	3.14	3.22	3.30	3.79	3.64	3.57	3.79	4.78	3.59	2.53	4.66
K_2O	0.71	0.58	0.68	2.42	1.27	2.17	1.73	2.00	2.30	2.05	4.75	2.88
TiO_2	1.42	1.03	1.03	2.26	1.37	0.91	1.06	0.96	0.70	0.75	0.84	0.75
P_2O_5	0.32	0.15	0.14	1.65	0.46	0.99	0.60	0.32	0.40	0.37	0.32	0.39
MnO	0.16	0.15	0.15	0.17	0.14	0.13	0.13	0.13	0.10	0.08	0.06	0.09
LOI	0.25	0.59	0.60	1.92	0.57	0.33	0.78	0.28	1.00	9.06	2.56	2.19
Total	99.93	99.28	99.72	99.24	99.55	98.96	99.60	99.44	98.65	99.14	99.08	98.74
Concentration in parts per million												
Ba	600	350	410	1,000	560	1,400	900	1,000	1,400	960	1,350	1,360
Co	48.8	42.8	41.3	49.3	37.2	33.8	40.1	26.1		16	15	12.5
Cr	392	294	271	244.	267	350	405.	98.1	47	52	60	29
Cs	0.27	0.28	0.28	0.69	0.39	1.0	0.90	0.67		0.49	7.5	0.56
Hf	2.3	2.4	2.3	4.4	3.7	5.0	3.8	4.1		3.2	7.31	4.56
Rb	17	10	11	38	24	37	33	44	46	37	150	48
Sb	0.25	0.13	0.19	0.13	0.30	0.27	0.21	0.21		0.26	0.48	0.21
Ta	1.1	0.27	0.24	1.5	0.93	1.1	0.82	0.90		0.42	0.79	1.0
Th	2.8	1.0	1.2	6.17	4.6	10.2	6.66	6.37	4.08	4.6	44.6	5.0
U	0.98	0.60	0.30	1.3	1.1	2.4	2.1	1.5	1.37	1.8	7.5	1.0
Zn	84	94	44	170	60	64	78	76	64	61	60	86
Zr	200	120	210	180	260	200	230	210	194	110	190	220
Sc	25.9	32.0	30.4	24.1	21.7	19.1	21.0	19.1		14.9	13.1	6.71
La	23.4	9.9	10	83.1	42.2	105	59.6	40.0	47	33.6	45.0	59.8
Ce	44.5	21	22	174	79.0	194	116	73.0	80	64.7	78.9	109
Nd	23	11	12	73	35	79	52	29		31	33	42
Sm	4.69	3.25	3.23	10.7	6.91	13.4	9.01	5.87		5.58	6.60	6.76
Eu	1.3	1.0	1.0	2.3	1.7	2.7	2.0	1.4		1.3	1.6	1.5
Tb	0.61	0.53	0.58	0.81	0.72	0.88	0.76	0.65		0.47	0.61	0.43
Yb	1.7	2.6	2.4	1.7	2.0	1.6	1.8	2.3		1.2	1.2	0.99
Lu	0.23	0.33	0.36	0.25	0.30	0.23	0.27	0.31		0.16	0.19	0.15
Sr	610	420	440	2,200	1,000	1,700	1,400	630	1,500	1,200	820	1,700
Nb	18	10	10	19	12	17	13	14	10	10	11	13
Y	19	20	23	19	23	23	23	24	20	16	19	12
Ni	180	110	98	130	200	190	260	51	27	67	27	47
Cu	138	56	58	158	58	54	65	46	35	60	22	21

Recalculated to 100% volatile free

Unit	Tnb	Tnb	Tnb	Tb	Tb	Tb	Tb	Tb	Ta	Tbta	Tt	Tpt
Field #	NR-546	NR-624	NR-486	NR-541	NR-645	NR-628	NR-544	NR-625	NR-839	NR-461-b	NR-517-a	NR-592-a
Lab. #	D-529410	D-529411	D-529405	D-529407	D-529414	D-529413	D-529408	D-529412	D-561976	D-529404	D-529406	D-529410
SiO_2	49.5	51.0	51.5	44.8	50.1	51.2	51	56	59.4	54.7	62.1	63.7
Al_2O_3	14.6	19.9	17.2	13.0	16.5	15.5	15.1	16.6	16.7	16.2	15.4	15.8
$FeTO_3$	11.7	9.55	9.38	13.7	8.91	7.4	8.7	7.55	6.01	6.59	5	4.82
MgO	8.43	7.65	6.89	9.06	8.47	9.32	9.92	4.71	3.87	5.35	3.28	1.9
CaO	10.1	9.66	9.65	9.25	8.91	8.62	8.08	6.86	6.19	9.52	5.41	4.71
Na_2O	2.88	3.22	3.25	3.39	3.85	3.69	3.62	3.82	4.13	3.99	2.62	4.83
K_2O	0.71	0.59	0.69	2.49	1.29	2.2	1.75	2.02	2.37	2.28	4.92	2.98
TiO_2	1.42	1.04	1.04	2.32	1.39	0.92	1.07	0.97	0.72	0.83	0.87	0.73
P_2O_5	0.71	0.15	0.14	1.7	0.47	1	0.61	0.32	0.41	0.41	0.33	0.4
MnO	0.16	0.15	0.15	0.17	0.14	0.13	0.13	0.13	0.1	0.09	0.06	0.09
Na_2O+K_2O	3.59	3.77	3.94	5.88	5.14	5.89	5.37	5.84	6.5	6.27	7.54	7.81

Location and Descriptions of analyzed (Table 2) samples:

NR-546. Olvine pyroxene basalt from outcrop at base of ledge on west edge of flat summit of Table Mountain. E edge Sec. 11, T. 7 N., R. 2 E.. Daisy Mountain quadrangle. Maricopa County. 33°57'51", 112°07'01". Plagioclase An 55 in laths as much as 0.6 mm long, subhedral to anhedral phenocrysts of olivine as much as 1.5 mm in diameter altered to iddingsite at margins, anhedral monoclinic pyroxene 0.05-0.2 mm in diameter in aggregates between plagioclase laths, glass, opaque mineral, and secondary carbonate.

NR-624. Olivine pyroxene basalt flow from base of Tnb. Contains concentrations of vesicles in pipes and round to elongate masses. On upper west slope of Dutch Butte in NW corner Sec. 35, T. 8 N., R. 1 E.. New River quadrangle. Maricopa County. 33°59'57",112°14'13". Helter-skelter laths of plagioclase An 68-72 as much as 4 mm long, euhedral to anhedral olivine as much as 0.6 mm in diameter rimmed by iddingsite, anhedral to subhedral monoclinic pyroxene as much as 0.5 mm in diameter between the plagioclase laths, and accessory opaque mineral and altered glass.

NR-486. Coarse-grained olivine-pyroxene basalt outcrop on crest of ridge W of center of Sec. 24, T 7 N., R. 1 E.. New River quadrangle. Maricopa County. 33°56'07", 112°12'55". Euhdral to subhedral laths of plagioclase An 65 as much as 5.6 mm long and one 3.3mm diameter block phenocryst, euhdral to subhedral olivine as much as 0.5 mm in diameter partly altered to iddingsite, subhedral to anhedral monoclinic pyroxene as much as 1 mm in diameter between the plagioclase laths, and accessory opaque mineral, and altered glass. Carbonate lines a vesicle.

NR-541. Olivine basalt near base of Tertiary section from outcrop on little knob just N of center of Sec. 14, T. 7 N., R 2 E. Daisy Mountain quadrangle. Maricopa County. 33°57'06", 112°07'27". Plagioclase An 52 in clots containing laths as much as 1 mm long and having sieve texture with pyroxene and opaque mineral. Euhedral to anhedral olivine phenocrysts, partly altered to iddingsite along margins, as much as 1.6 mm in diameter and one glomerophenocryst 2 mm in diameter. Subhedral to anhedral monoclinic pyroxene as much as 0.3 mm long, euhedral to anhedral biotite, opaque mineral and altered glass.

NR-645. Porphyritic olivine-pyroxene basalt from outcrop near the base of the Tertiary section. NW of center Sec. 16, T. 7 N., R. 2 E.. New River quadrangle, Maricopa County. 33°57'11", 112°09'44". Euhedral to anhedral plagioclase An 56 phenocrysts as much as 2 mm long and as 0.15 mm long grains in matrix, euhedral to anhedral olivine phenocrysts as much as 3 mm in diameter and 0.04

mm diameter grains in matrix, locally altered to iddingsite, euhedral to subhedral phenocrysts of monoclonic pyroxene as much as 1 mm long and 0.05-0.15 mm grains in matrix, opaque mineral, and glass.

NR-628. Fine-grained porphyritic olivine-pyroxene basalt from near base of Tertiary section. Outcrop on E side of top of 2257' hill, SW1/4 Sec. 22, T. 7 N., R. 3 E. New River quadrangle. Maricopa County. 33°55'53", 112°08'48".Euhedral to subhedral phenocrysts of olivine as much as 0.7 mm in diameter and prismatic phenocrysts of monoclinic pyroxene as much as 0.6 mm long and in matrix of pyroxene and plagioclase having an average grain size of about 0.05 mm. Accessory opaque mineral and biotite.

NR-544. Porphyritic olivine-pyroxene basalt from near the base of the Tertiary section from outcrop on E side New River, NW1/4 Sec. 14, T. 7 N., R. 2 E.. New River quadrangle. Maricopa County. 33°57'34", 112°07'55". Euhedral to anhedral phenocysts of olivine as much as 1.6 mm long, euhedral to subhedral phenocrysts of monoclinic pyroxene as much as 1 mm long, plagioclase laths as much as 0.5 mm long and 0.02-0.06 mm in matrix, and accessory opaque mineral, biotite, and glass.

NR-625. Porphyritic olivine-pyroxene basalt flow about 20 m below base of New River Basalt. Outcrop on steep west-facing slope. SE1/4 Sec. 27, R.8 N., R. 1 E.. Black Canyon City quadrangle. Maricopa County. 34°00'19", 112°14'26". Olivine and altered olivine as much as 0.5 mm in diameter, euhedral plagioclase phenocrysts An 50-60 as much as 1 mm long having weak normal and oscillatory zoning, a glomerophenocryst of plagioclase 2.3 mm long and altered glass. Contains resorbed quartz zenocryst 3 mm in diameter having a rim of monoclinic pyroxene. Accessory opaque mineral.

NR-839. Pyroxene andesite from float block in gully west of plug. On S line Sec. 29, T. 8 N., R. 3 E. Squaw Creek Mesa quadrangle. Maricopa County. 34°00'05", 112°04'42". Euhedral to subhedral monoclinic pyroxene as much as 1 mm long and tiny grains in the matrix, Normally zoned plagioclase An 65-40 as much as 0.2 mm long, opaque mineral, and accessory euhedral to subhedral brown hornblende as much as 1 mm long. Mafic minerals and rock fragments of andesite have rims of fine-grained pyroxene and opaque mineral.

NR-461-b. Partly altered hornblende andesite forming a plug 0.7 km in diameter. From outcrop in SW corner of New River quadrangle on W edge Sec, 11, T. 6 N, R. 1 E.. Maricopa County. 33°52'47", 112°14'11". Strongly zoned euhedral plagioclase phenocrysts as much as 2.5 mm long; compositions range An 32-62. Normal and reverse zoning. Phenocrysts of altered amphibole as much as 1 mm long in a matrix of 0.05-0.3 mm plagioclase, altered amphibole, biotite, and calcite. Accessory opaque mineral.

NR-517-a. Biotite latite from exogenous dome from outcrop in wash S part Sec. 5, T. 7 N., R. 2 E.. New River quadrangle. Maricopa County. 33°58'29", 112°10'41". Phenocrysts of euhedral to subhedral biotite to 1.0 mm in diameter, euhedral to subhedral monoclinic pyroxene as much as 0.9 mm long, and hornblende in a matrix of glass containing laths of plagioclase averaging 0.04 mm long. Also contains zenocrysts of garnet, orange-brown hornblende, and feldspar(?) rimmed by opaque minerals and in turn by biotite. Contains clots of pyroxene and biotite, and of hornblende, pyroxene, and sphene.

NR-592-a. Biotite-tracheydacite from 0.5 km diameter plug forming Gavalin Peak from north side of peak. Just N. of center of Sec. 35, T. 7 N., R. 2 E.. Daisy Mountain quadrangle. Maricopa County. Euhedral phenocrysts of plagioclase An 35 as much as 1 mm long and hornnblende as much as 3 mm long mostly altered to opaque mineral in a matrix of plagioclase, opaque mineral, carbonate, and glass with a grain size of 0.5-0.1 mm. Accessory apatite.

Plots of the analyses of Tertiary igneous rocks on an alkali-silica diagram (fig. 7A) show that the older basalts are trachybasalt to trachyandesite, whereas the younger basalt is thoelietic. The plug in the southwest corner of the map area is basaltic trachyandesite, and the Gavilan Peak plug is tracheydacite. The exogenous dome in the north part of the map area is a trachyandesite. The plug of basaltic trachyandesite is highly altered so its assignment to that composition should be viewed with some caution. The older igneous rocks are high K, whereas the younger basalts are medium-K.

The older basalts are richer in light rare earth elements and many other minor elements, except for heavy rare earth elements, than the younger basalts (fig.7B). They have light rare earths 100-300 times chrondite compared to 30-70 times chrondite for the younger basalts. The younger basalts have La/Yb ratios of 4-14; the older basalts have ratios of 17-65, and the subvolcanic plutons 28-60. Th/U ratios are 1.6-4.7 for the younger basalts, 3.2-4.7 for the older basalts, and 2.6-5.9 for the subvolcanic plutons. Rare earth patterns of rocks analyzed from all three categories show no Eu anomalies. These values can be compared with those based on a regional study by Leighty and Glascock (1994) in which 16-30 Ma rocks are high K and have very high Ba and Sr, but have relatively low Rb. Their study shows that east of the New River area, 22-17 Ma rocks are medium K alkali basalts. In the New River area the older basalts are high-K trachybasalt and basaltic andesite, and they have an Rb content about three times that of the younger basalts, similar to the difference in Sr and Ba content between the two ages of basalt.

The three subvolcanic plutons for which we have rare earth data have a lower heavy rare earth content than the basalts. Content of other minor elements is similar to that of the older basalts. However, trachyandesite of the exogenous dome has an anomalously high Th, U Rb, and Cs contents compared to all the other rocks analyzed.

Mineral Resources

The principal mineral resource in the New River area is gravel. This resource is valuable because of proximity to the Phoenix urban area and transportation routes. The best gravels containing mostly unweathered rock and small amounts of clay minerals, are in the alluvium (Qal) and terrace gravel (Qtg) along the Aqua Fria and New Rivers. Much of the alluvium along the Aqua Fria River is beneath Lake Pleasant, when it is full. The level of Lake Pleasant has been raised to 1,710 feet altitude since the topographic base was made. In the northwest part of the area alluvium and terrace gravel of the Aqua Fria are accessible. The alluvium and terrace gravel along the New River constitute the largest and most accessible reserve of gravel in the map area. These deposits contain some boulders of basalt or granite even in the south part of the area; large boulders constitute a greater proportion of the deposits along the New River in the north part of the area. The larger tributary streams, such as Moore Gulch, Skunk Creek, and Sweat Canyon, have smaller deposits of gravel. Older alluvial deposits (Qgm, Qgo, Tgy) are potential sources for gravel, although they contain more silt and clay, and may have some weathered rock pieces and be cemented by caliche within a few meters of their surfaces. Another possible gravel resource is the talus and colluvium (Qtc), which is accessible from Sweat Canyon in the southwest part of the area. These deposits are composed of fragments of basalt, but they locally have clay-rich matrix derived from interbedded tuffs.

The phyllitic slate and graywacke unit (Xps) has been quarried in several places, probably for surfacing driveways. By far the largest quarry being operated operation during mapping was on the road along the New River at the corner of Secs. 5,6,7,8, T. 7 N., R. 3 E. .

Thick beds of lithic tuff in the tuff and conglomerate unit (Ttc) have been prospected in the northern part of the area, possibly for their absorptive characteristics.

The metavolcanic rocks of sequence 1 have been prospected for massive sulfide deposits without any success to date. The rocks of this sequence near the New River area contain two mines that produced copper, lead and silver (see DeWitt, 1995 and references). One was on the Agua Fria River 6 km north of the map area, and the other was in Moore Gulch 1 km north of the area. Prospects are most commonly in

red-weathering areas of rock that contain ferruginous metachert or in shears, some of which contain quartz veins. A few of the prospects contain sparse secondary copper minerals, but most are apparently barren.

Prospects containing a few secondary copper minerals in metavolcanic rocks of sequence 2 at and adjacent to the Daisy Mine are on shear zones and thin quartz veins.

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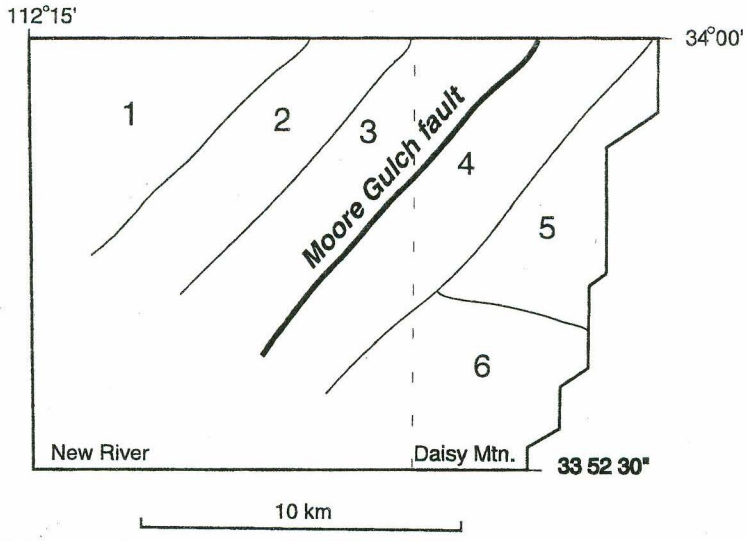

Figure 1. Areas of structural analysis of Proterozoic rocks.

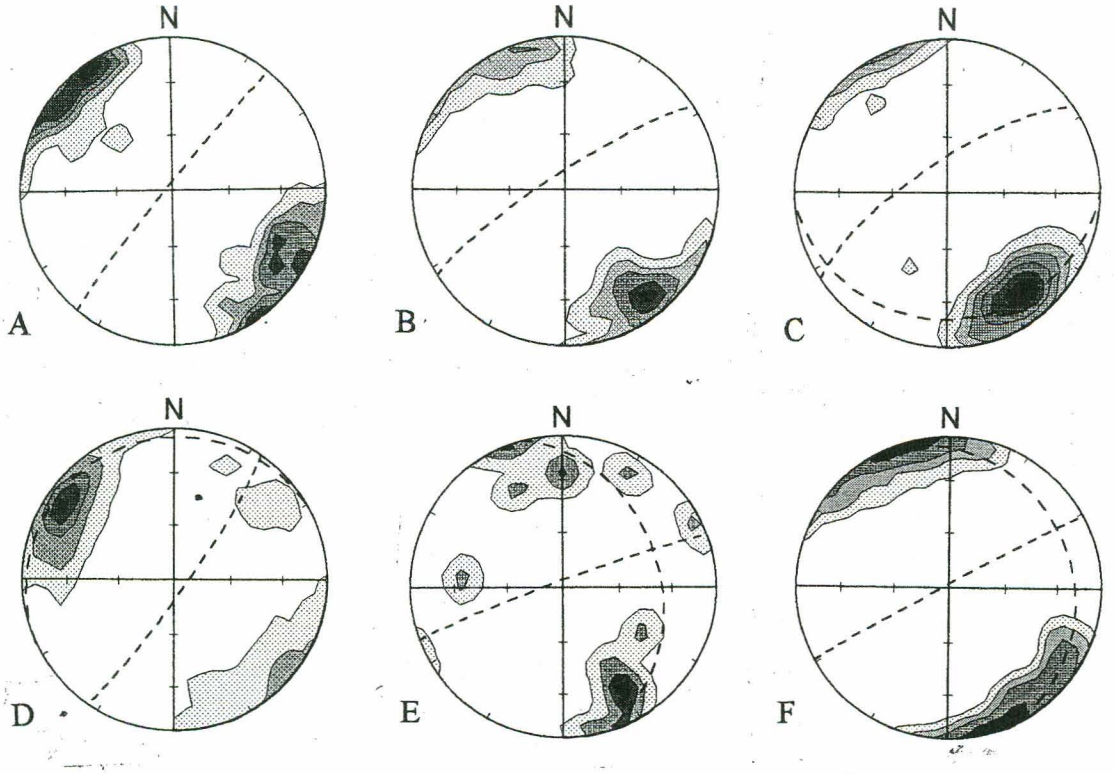

Figure 2. Poles to cleavage and foliation. A, area 1, n= 45. Contours 0, 2, 4, 6, 8. B, area 2; n=31. Contours 0, 2, 5, 10, 15. C, area 3; n= 128. Contours 0, 3, 6, 10, 15, 20. D, area 4; n=225. Contours 0, 5, 10, 15, 20. E, area 5; n=14. Contours 0, 2, 4, 6. F, area 6; n=96. Contours 0, 2, 5, 10. n, number of measurements. The northeast-trending dashed great circles represent planes perpendicular to the maximum concentration of poles to foliation and represent a statistical foliation direction from all the measurements in the area. The second great circle in C-F represents the plane of a girdle through the poles to cleavage. A line perpendicular to that plane is the axis of rotation of the points to form the girdle. All diagrams in figures 2-5 are equal area projections on the lower hemisphere.

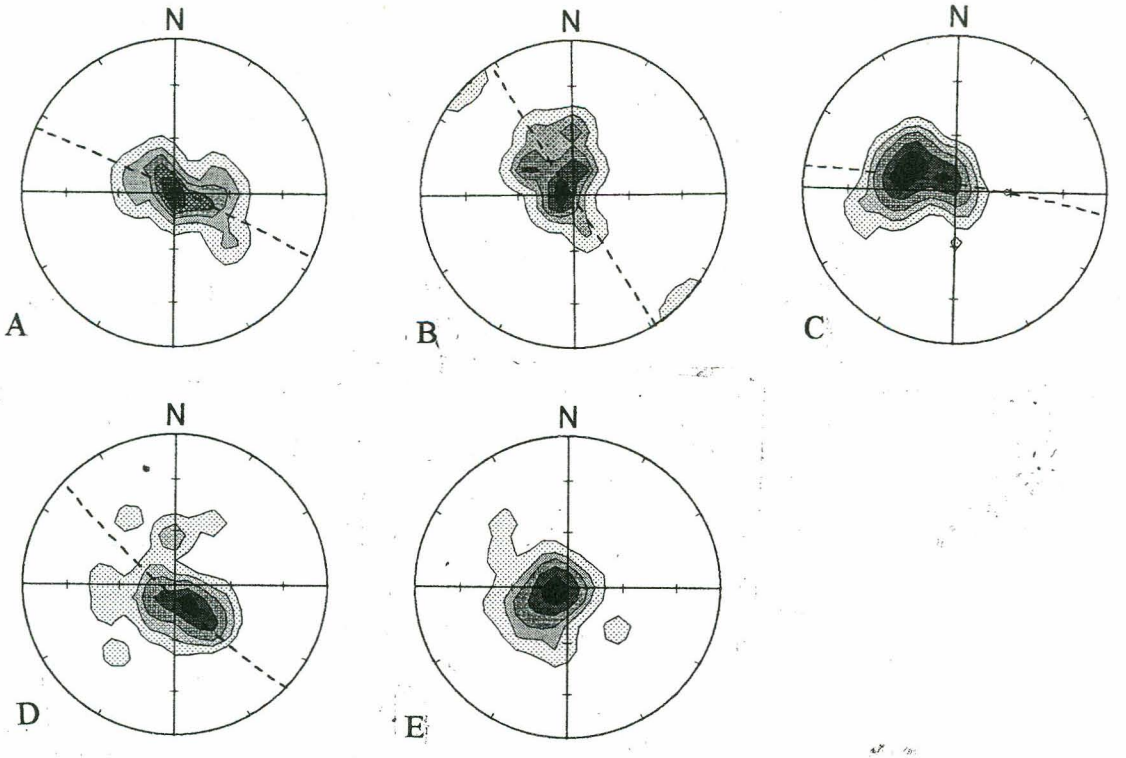

Figure 3. Stretching lineation. A, area 1; n=15. Contours 0, 2, 4, 6, 8, 10. B, area 2; n=18. Contours 0, 2, 4, 6, 8. C, area 3; n=81. Contours 0, 5, 10, 15. D, area 4; n=44. Contours 0, 2, 5, 10, 15. E, area 6; n=44. Contours 0, 3, 6, 10, 15. Dashed line, plane of poorly developed girdles. Axes of the girdles all trend northeast and plunge gently northest or southwest.

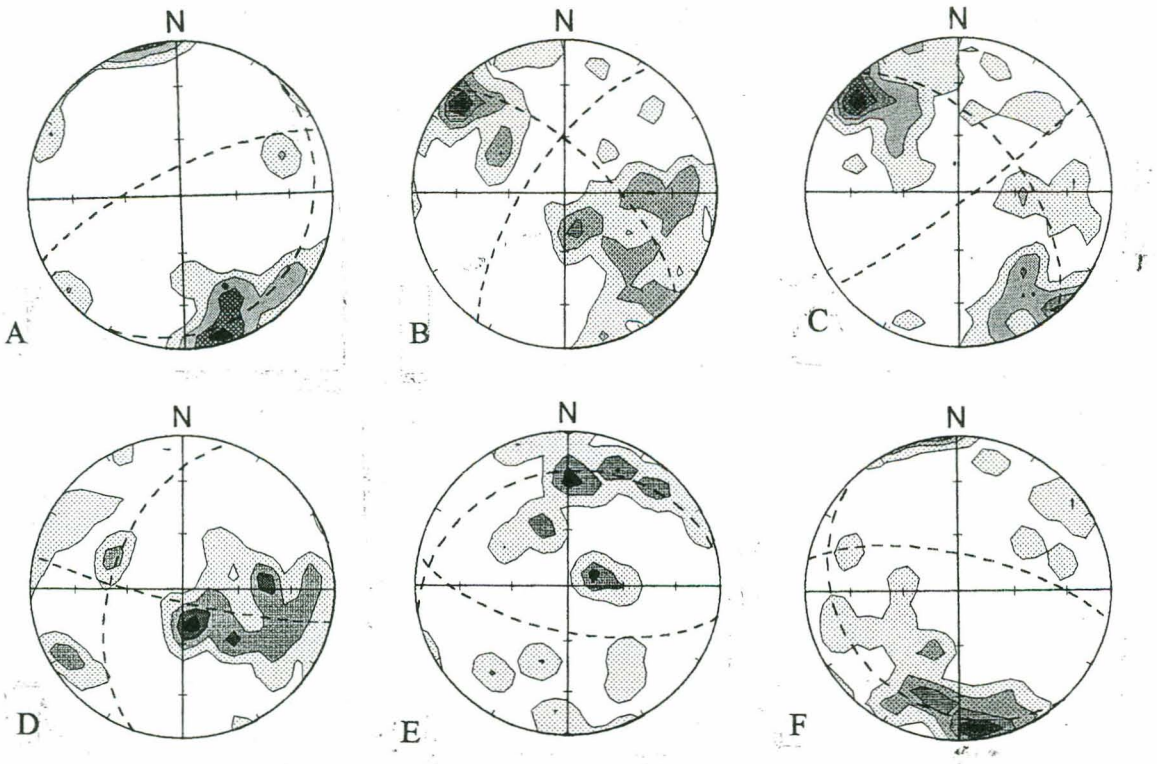

Figure 4. Poles to bedding. A, area 3; n= 20. Contours 0, 2, 6, 10. B, area 4, n=205. Contours 0, 2, 4, 6, 8, 10. C, slate, phyllitic slate, and graywacke (Xps) in area 4; n=97. Contours 0, 2, 4, 6, 8, 10. D, rhyolites in area 4 (Xrl, Xrh, and Xp). n=107. Contours 0, 2, 4, 6. E, area 5; n=22. Contours 0, 2, 4. F, area 6; n=36. Contours 0, 2, 4, 6, 8. Dashed line, plane of girdle. In A, B, C, D plane is perpendicular to the statistical point maxima and trends northeast and has moderate to steep dips. In E and F the plane perpendicular to the statistical maximum trends northwest and dips steeply. The second planes represent a great circle through the girdle formed by the poles to the bedding. That girdle is poorly developed in B,C, and D and better developed in A, E, and F.

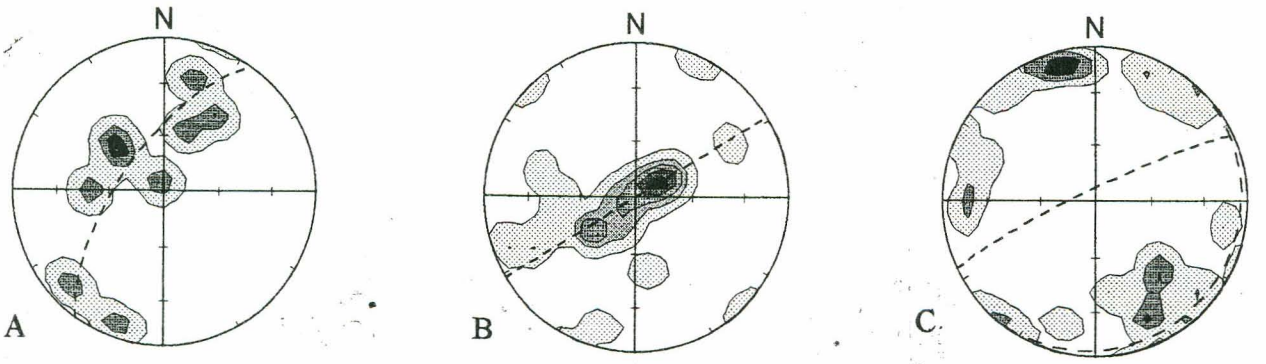

Figure 5. Minor folds. A, fold axes in area 3, n=9. Contours 0, 2, 4. B, fold axes in area 4; n=21. Contours 0, 2, 4, 6, 8. C, axial planes of minor folds in area 4; n=25. Contours 0, 2, 4. Dashed line is great circle formed by plane of girdles formed by the fold axes and axial planes. In C the northeast trending, steeply dipping plane is perpendicular to the statistical maximum of the distribution of the poles.

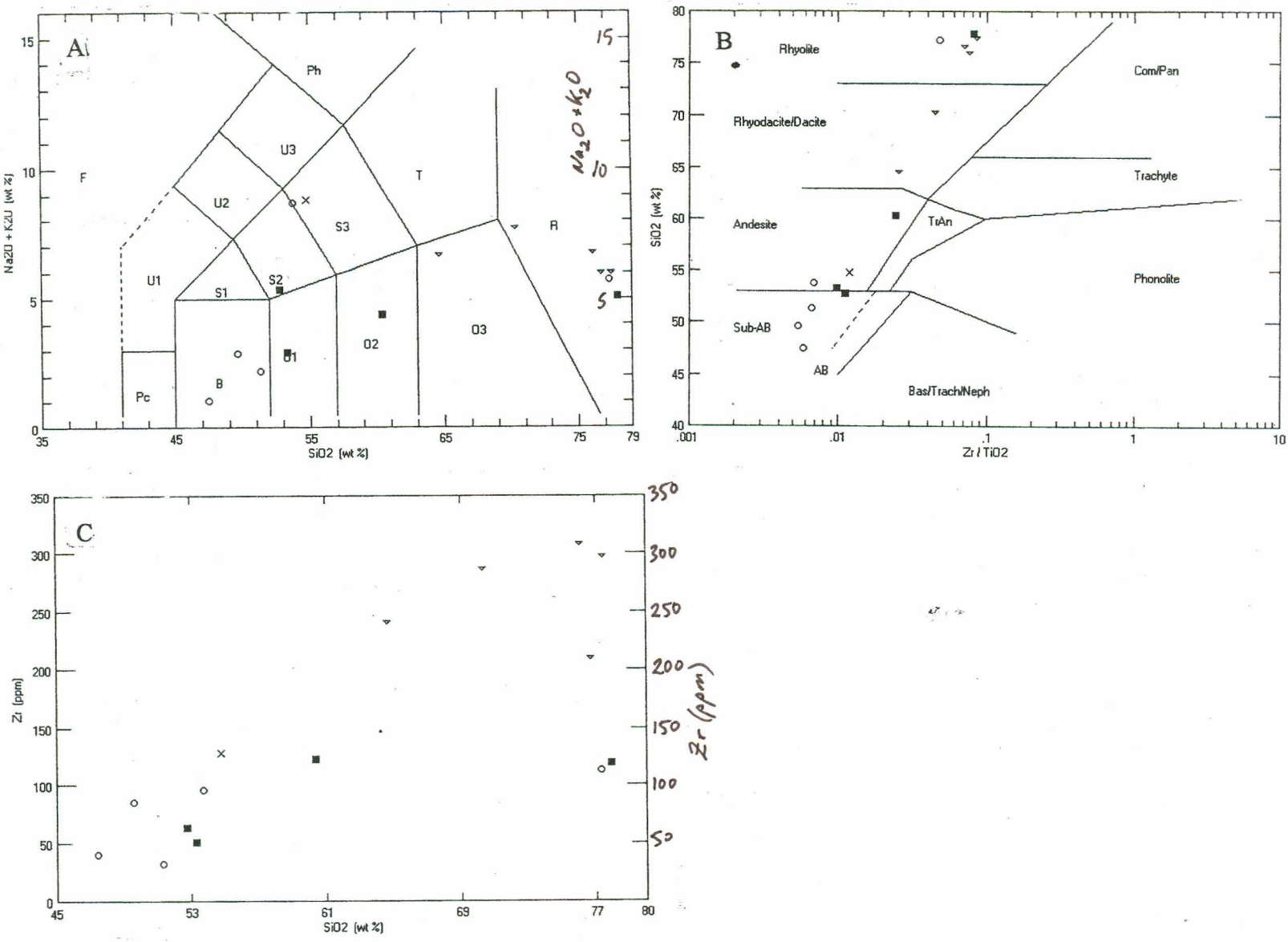

Figure 6. Chemical diagrams for Proterozoic metavolcanic rocks. Analyses recalulated to 100% after deduction of volatiles. Circles, samples from group 1 rocks; filled squares, samples from group 2 rocks; inverted triangles, samples from group 3 rocks; cross, altered volcanic rock in phyllite unit (Xp) in group 3 rocks. A, alkali-silica. Fields of interest (Le Bas and others, 1986); B, basalt, 01, basaltic andesite; O2, andesite; 03, dacite;S2 basaltic trachyandesite; S3 trachyandesite; r, rhyolite. B,SiO_2-Zr/TiO_2 (Floyd and Winchester, 1978). C, Zr-SiO_2.

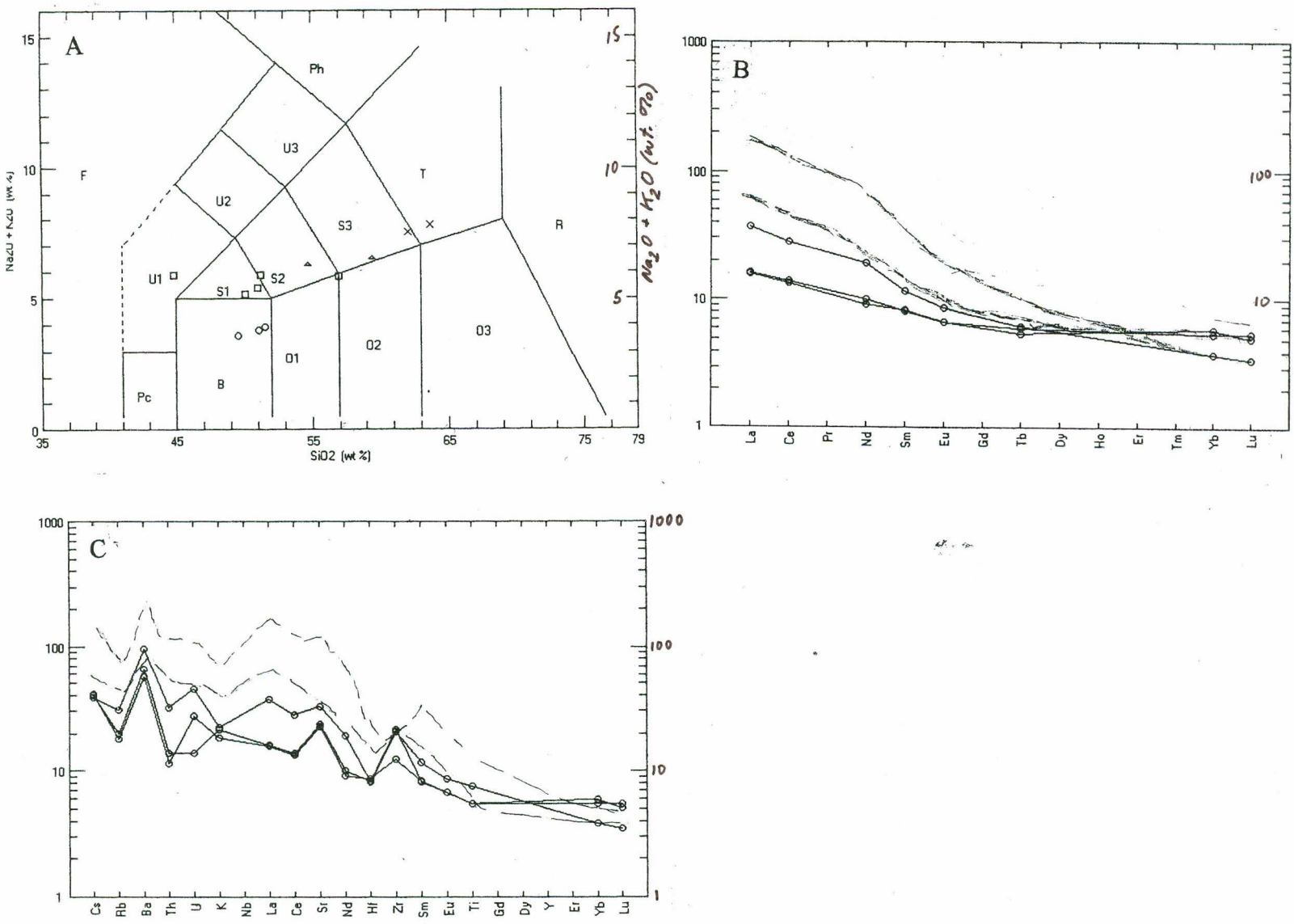

Figure 7. Chemical diagrams for Tertiary igneous rocks. A, alkali-silica. SiO_2 values recalculated to 100% volatile free. Circles, samples of New River Mesa Basalt of Gomez (1979) (Tnb); squares, samples of basalt (Tb); triangles, samples from intrusive and flow rock judged to be andesite in hand specimen and thin section; cross, samples of intrusive rock called latite based on hand samples and thin sections. Fields of interest (Le Bas and others, 1986): B, basalt; 01, basaltic andesite; 02, andesite; S1, trachybasalt; S2, basaltic trachyandesite; S3, trachyandesite; T, trachydacite or trachyite. B, Rare earths in New River Mesa Basalt of Gomez (1979) (Tnb); field of values in basalt (Tb) shown by dashed lines. C, Spider diagram for samples of New River Mesa Basalt of Gomez (1979) (Tnb). Field of values from samples of basalt (Tb) shown by dashed lines.