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AGE AND ORIGIN OF THE DARROUGH FELSITE, SOUTHERN TOIYABE RANGE, NEVADA

By R. C. SPEED [1] and E. H. McKEE
Evanston, Ill., Menlo Park, Calif.

Abstract.—The name Darrough Felsite was originally assigned to a body of fine-grained quartzofeldspathic igneous rock probably greater than 3 km thick that is exposed continuously over 100 km² in the southern Toiyabe Range of central Nevada. The Darrough was supposed to consist mostly of intrusive rocks of probable Permian age. Reexamination of parts of the Darrough Felsite indicates that it is Tertiary and has no genetic affiliation to pre-Tertiary sedimentary and volcanic rocks of the Toiyabe Range. The Darrough constitutes an enormously thick succession of crystal-lithic tuff, tuff breccia, crystal tuff, and volcanogenic sedimentary breccia and sandstone. The tuffaceous rocks are strongly compacted where ash particles are the dominant constituent but are much less compacted where lithic fragments and crystals constitute a rigid framework. Much of the Darrough Felsite may have undergone extensive silicification, probably as a postcompaction event. Contact relations of the Darrough Felsite indicate that it is younger than pre-Tertiary rocks of the southern Toiyabe Range and the Ophir pluton, here dated at 53.9 m.y. (K-Ar, biotite). Three K-Ar ages of minerals from tuff of the Darrough are 26.1, 22.7, and 22.3 m.y., suggesting a middle Tertiary age. A large dike intruding the Darrough, previously assigned a Jurassic age, gives a K-Ar-biotite age of 29.4 m.y. We tentatively interpret the Darrough Felsite to represent an accumulation of ash and breccia flows in a volcanotectonic depression.

The name Darrough Felsite was applied by Ferguson and Cathcart (1954) to a large mass of fine-grained siliceous igneous rock that crops out in the southern Toiyabe Range of central Nevada (fig. 1). They believed the mass to be mostly intrusive and suggested that a genetic association exists between it and the nearby partly volcanic Pablo Formation. Because the Pablo was questionably assigned to the Permian, the Darrough Felsite also was considered to be Permian(?). Taken literally, Ferguson and Cathcart's (1954) interpretation of the Darrough Felsite indicates a major episode of silicic volcanism in the southern Toiyabe Range in Permian(?) time. If their age assignment is correct, silicic volcanism must be included in Permian(?) paleotectonic reconstructions of western and central Nevada.

Preliminary conclusions presented below on the age, origin, and geologic relations of the Darrough Felsite differ from those of Ferguson and Cathcart (1954) and indicate that the Darrough is a thick pile of siliceous tuff, breccia, and possibly lava of middle Tertiary age. We find no genetic relation between the Darrough and the Pablo Formation. There is no convincing evidence of Permian silicic volcanism in the area of the southern Toiyabe Range.

Three possible origins are considered for the Darrough Felsite. It may represent volcanic and epiclastic rocks that filled a volcanotectonic depression; it may be pyroclastic rock that accumulated around the vent of a volcano and became extremely thick owing to caldera collapse and infilling, possibly accompanied by domal intrusion and resurgence; or it may be the product of a large endogenous and exogenous flow-dome complex.

The Darrough Felsite is a physically challenging body of rock to study in the field owing to precipitous slopes and great relief. Complete areal investigation of the unit will require considerable time, and the present preliminary study is of the more accessible parts of the unit.

GEOLOGIC SETTING

The distribution of the main body of the Darrough Felsite, as modified from Ferguson and Cathcart (1954), is shown in figure 1. These authors also delineated a sizable body of Darrough Felsite north of the mouth of Peavine Canyon, about 15 km to the south. We have not examined that body, but F. J. Kleinhampl, oral commun., 1971) believes that it is correlative with rocks mapped as Darrough Felsite of the main body as shown in figure 1.

Rocks of pre-Tertiary age include early Paleozoic and Permian rocks (Ferguson and Cathcart, 1954), Pennsylvanian rocks (F. J. Kleinhampl, oral commun.,

[1] Dept. Geological Sciences, Northwestern University.

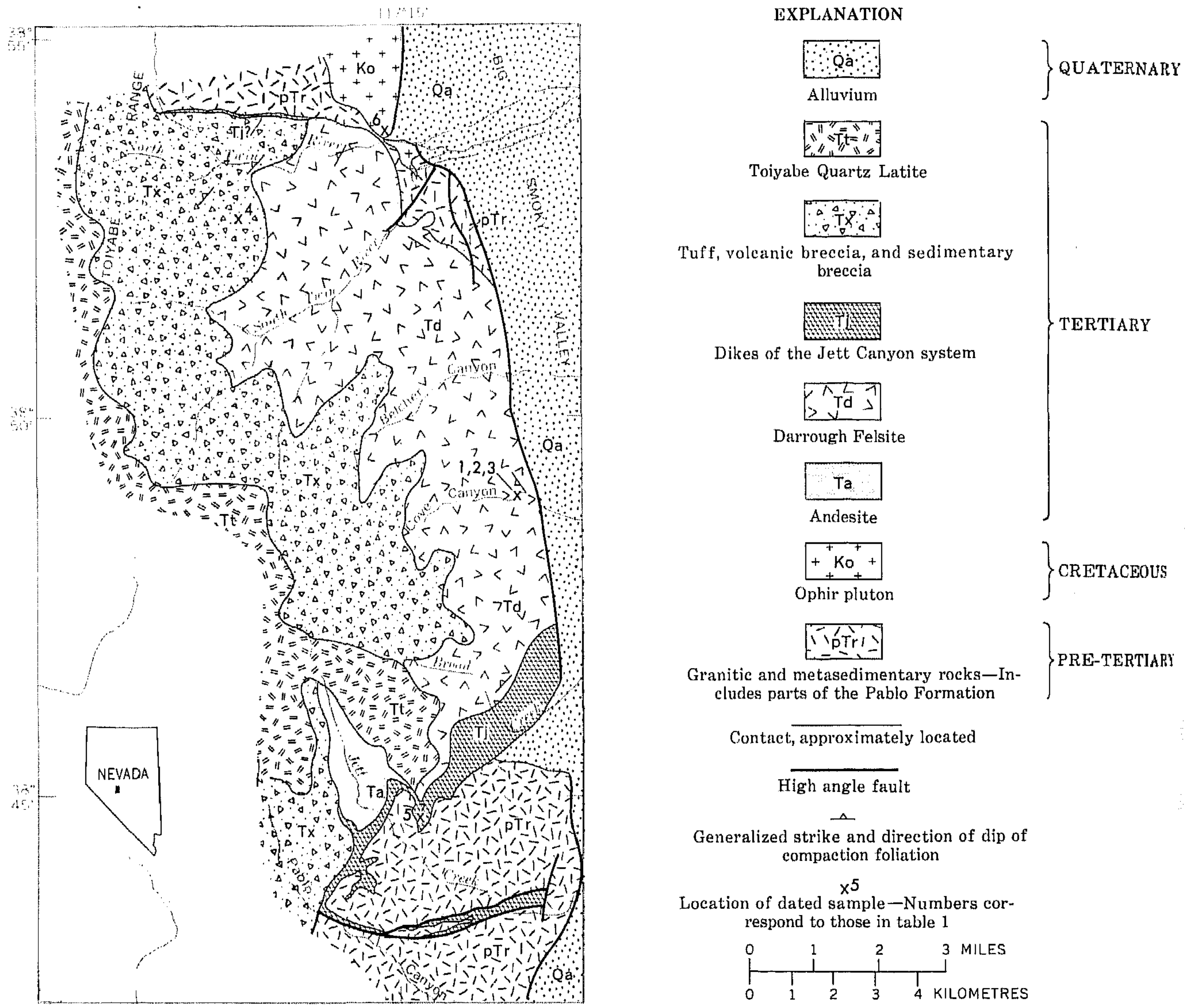

FIGURE 1.—Geologic map of part of the southern Toiyabe Range, Nev. Modified from Ferguson and Cathcart (1954).

1971), and the Pablo Formation. These are grouped in a single map unit (fig. 1). The Pablo Formation was thought by Ferguson and Cathcart (1954) to lie conformably on Permian conglomerate and to be Permian(?) in age, but it is allochthonous in the Toiyabe Range (Speed, 1973) and can be dated only as older than the 53.9-m.y. K-Ar age of the Ophir pluton (table 1) which intrudes it. The Pablo contains abundant mafic volcanic rock, chiefly basaltic pillow lava, and bedded tuff. SiO_2 contents of two fresh-looking clinopyroxene-bearing Pablo basalts are 45.0 and 48.0 percent, and K_2O contents are less than 0.25 percent. No siliceous volcanic rocks are recognized in the Pablo. All the pre-Tertiary rocks contain at least two sets of tectonic folds, none of which is recognized in the Darrough Felsite.

Tertiary extrusive rocks comprise three units in figure 1, in addition to the Darrough Felsite, with andesite constituting a probable pre-Darrough, basal Tertiary unit. Numerous small erosional remnants of andesite that overlie Mesozoic and Paleozoic rocks in Pablo and Jett Canyons are cut by granitic dikes of the Jett Canyon system, one of which in Jett Canyon is dated at 29.4 m.y. (table 1). Though the Darrough Felsite and the andesite are not in contact, intrusive relations of the dikes and the andesite and the dikes and the Darrough suggest that the andesite is older than the Darrough. We suggest that the andesite may be correlative with similar rocks dated at about 35 m.y. that form the base of Tertiary sections to the north, northwest, and northeast of the area of figure 1 in the Clan Alpine, Shoshone, Toiyabe, and Simpson Park

TABLE 1.—K-Ar *analytical data from samples of the Darrough Felsite and associated rocks, southern Toiyabe Range*

[Constants: $K^{40}\lambda_e = 0.584 \times 10^{-10}$/yr; $\lambda\beta = 4.70 \times 10^{-10}$/yr; atomic ab ndant $K^{40} = 1.19 \times 10^{-4}$. Argon analyzed by standard isotope dilution techniques on a Neir-type 6-in-radius 60°-sector mass spectrometer. K_2O analysis by flame photometer using a lithium internal standard. Sample locations in fig. 1]

Sample	Name and relation to Darrough Felsite	Mineral and K_2O in wt percent	Radiogenic Ar^{40} (mol/g $\times 10^{-10}$)	Radiogenic Ar (percent)	Apparent age (m.y.)
1	Darrough Felsite	Sanidine, 13.79.	4.577	47	22.3±0.8
2	do	Sanidine, 11.37.	3.838	56	22.7±0.8
3	do	Hornblende, 2.37, 2.40.	.949	49	26.7±1.0
4	Tuff of intermediate unit.	Sanidine, 12.19.	4.125	56	22.7±0.8
5	Quartz monzonite dike intrusive into Darrough Felsite.	Biotite, 6.8.	2.981	66	29.4±0.8
6	Ophir pluton (older than Darrough Felsite).	Biotite, 7.29.	5.884	83	53.9±1.5

Ranges (Riehle and others, 1972; McKee and Stewart, 1971; McKee, 1968).

The youngest unit of Tertiary volcanic rocks is the Toiyabe Quartz Latite, a regionally extensive succession of distinctive ash-flow tuffs. The Toiyabe Quartz Latite contrasts markedly with the Tertiary rocks below it because it contains a hign proportion of only moderately compacted tuffs, in sharp contrast to the strongly compacted and locally silicified subjacent tuffs. A K-Ar age of 21.5 m.y. was obtained for the Toiyabe Quartz Latite about 10 km west of figure 1, (Kleinhampl and Ziony, 1967). The basal contact of this unit shown in figure 1, taken from Ferguson and Cathcart (1954), is apparently an unconformity.

A third Tertiary unit of tuff, volcanic breccia, and sedimentary breccia (fig. 1) corresponds to the Esmeralda Formation of Ferguson and Cathcart (1954) and was designated the middle volcanic unit by Kleinhampl and Ziony in 1967. Although it has some lithologic similarities to the Esmeralda, it is probably mostly older than that formation in its type area. The unit contains tuff and epiclastic volcanic rocks that lie below the Toiyabe Quartz Latite and above the Darrough Felsite over most of the area of figure 1 but below the Toiyabe Quartz Latite and above Tertiary andesite west of Jett Canyon where the Darrough is absent. Future work may prove that this unit includes several unrelated Tertiary units and, in particular, that much of it should be included in the Darrough Felsite.

In the North Twin River drainage (fig. 1), the basal rocks of this unit are about 100 m of massive epiclastic breccia, microbreccia, and pebbly feldspar-chert sandstone. The breccias contain clasts of pre-Tertiary rocks and Tertiary andesite, dense siliceous volcanic rocks, and quartz. Well-developed bedding in the sandstones is concordant with compaction foliation in subjacent Darrough Felsite. These sedimentary rocks were assigned by Ferguson and Cathcart (1954) to the Permian Diablo Formation, but such correlation is unlikely because the type Diablo does not contain volcanic fragments and feldspar grains common in these sedimentary rocks. The sedimentary rocks lie above the Darrough as mapped in figure 1, and they resemble epiclastic rocks locally within the Darrough.

The tuff, volcanic breccia, and sedimentary breccia are conformably overlain by at least 600 m of densely compacted ash-flow tuff also included in the unit. The tuff contains sanidine, plagioclase, and quartz phenocrysts and sparse aphanitic lithic fragments. Eutaxitic structures are prevalent, but compaction zonation is unrecognized. The tuff has a smaller proportion of crystals and is slightly less dense than typical Darrough Felsite. The greater density of the Darrough is thought to be due to thorough silicification, however, rather than greater compaction. A K-Ar date on sanidine from this tuff (No. 4, table 1) is 22.7±0.8 m.y., a nearly identical age to that of two sanidine separates from the Darrough Felsite. The age, degree of compaction, lithologies, and attitude of rocks in the tuff and breccia unit in the North and South Twin River drainages suggest a genetic affiliation of such rocks with the Darrough.

West of Jett and Pablo Canyons (fig. 1), the tuff and breccia unit contains more variably compacted rocks. Such rocks lie above Tertiary andesite, and their relations with the Darrough are unclear.

Figure 1 shows segments of a system of steep dikes that cut pre-Tertiary rocks, Tertiary andesite, and some parts of the Darrough Felsite. These dikes consist variably of rhyolite porphyry, porphyritic granitic rocks, breccia, and, in places, tuff. The siliceous dikes occur in an anastomosing network, here called the dike system of Jett Canyon. Lithic variations in this dike system are both vertical and subhorizontal, perpendicular to the walls, as well as along strike. In general, granitoid rocks occur where the dikes are thick (as much as 500 m), and rhyolite porphyry in dikes that are narrower than 10 m. Breccia dikes contain clasts of older rocks, including Tertiary andesite. Serpentinite occurs along thin dikes and faults between dikes.

DARROUGH FELSITE AS A LITHIC UNIT

Previous interpretations

Ferguson and Cathcart (1954) observed that the Darrough Felsite is largely fine-grained igneous rocks consisting of quartz, K-feldspar, plagioclase, biotite, and devitrified glass. They further noted that well-defined flow banding is widespread and that the rocks are porcelaneous at places but granitoid at others. They felt that such textures perhaps best indicated that siliceous lava flows make up much of the Darrough Felsite. Their interpretation that the contacts of the Darrough were all intrusive with respect to older rocks, however, apparently forced a conclusion that the unit is largely an intrusion. Furthermore, Ferguson and Cathcart (1954) found felsite-pebble conglomerate interbedded with so-called flow rocks within the Darrough Felsite. Apparently because of the seeming conflict that the Darrough contains intrusive, extrusive, and sedimentary rocks, Ferguson and Cathcart (1954) assigned the layered rocks, at least in part, to inliers or pendants of the Pablo Formation within the intrusive mass of the Darrough.

A pre-Tertiary age of the Darrough Felsite was assumed by Ferguson and Cathcart (1954) because the Darrough is intruded by granitic rocks assigned by them to the Jurassic(?). They reasoned that an apparent relationship of the Darrough Felsite and the Pablo Formation made probable a Permian age for the Darrough. The correlation of Darrough Felsite and the Pablo Formation was influenced further by the assumption that siliceous flows, lithologically like Darrough Felsite, occur in the Pablo Formation elsewhere.

New observations

Reconnaissance investigations indicate that the Darrough Felsite is a thick sequence of subtly layered rocks consisting of variably compacted crystal-lithic siliceous tuff, tuff breccia, lava, volcanic and sedimentary breccia, and sandstone. The exposed thickness exceeds 2,000 m, and the total thickness is likely to be far greater. Tuff and tuff breccia appear to dominate the sequence. Such rocks are characteristically rich in crystals (average 40 percent phenocrysts), and they commonly contain an abundance of small lithic clasts as well as crystals. Some vertical intervals exceeding 50 m are made up of very coarse unsorted epiclastic breccia whose clasts are of various sedimentary and metasedimentary rocks, granitic rocks, and other siliceous igneous rocks. Associated with these breccias are local, generally thin intervals of bedded gravel- and sand-sized lithic particles and quartz and feldspar crystals.

Intrusive rocks, such as those mapped by Ferguson and Cathcart (1954) at South Twin River, do exist in the Darrough Felsite. Our reconnaissance indicates, however, that the proportion of intrusive rocks in the Darrough is not as large as originally supposed.

All the layered rocks of the Darrough Felsite, including tuffs, breccias, flows, and sedimentary types, are extremely hard and nonporous. Such properties appear to be uniform throughout the Darrough regardless of degree of compaction of the tuff or degree of sorting in the sediment. Indeed, measurements of the density of tuffs in the Darrough indicate uniformly negligible porosity. The entire body appears to be silicified to some extent, and there is evidence of hydrothermal alteration and weak metamorphism at many places.

The lithologic zoning, bedding in sedimentary rocks, and compaction foliation in tuff are coplanar within local areas. Departures from parallelism exist where compaction foliation of the tuffs is bent in ramp structures and small flowage folds, especially near the base of the unit. General attitudes of planar structures are indicated at several places in figure 1; maximum dips are about 45°, but in most places dips are nearly horizontal.

The basal contact of the Darrough Felsite appears to be a regular surface and where it can be walked out near the mouth of North Twin River, it is planar over distances of 100 m. At this locality the contact is an angular unconformity with folded pre-Tertiary rocks. Farther west, the northern boundary of the Darrough is a high-angle fault intruded by a dike lithologically correlated with the dike system of Jett Canyon. At Broad Canyon, a wide segment of the Tertiary Jett Canyon dike system intrudes the contact of the Darrough Felsite and older rocks. Layering in the Darrough at Broad Canyon is concordant to the trend of the dike and is discordant to bedding and fold elements in older rocks to the southeast.

It seems clear that the Darrough Felsite was not deformed with rocks assigned to the Pablo or older pre-Tertiary formations, whose penetrative deformation was completed before emplacement of the Darrough. Furthermore, there appears to be no particular spatial association of the Darrough Felsite and any older rock unit. The Darrough is not a genetic affiliate of the Pablo Formation, as suggested by Ferguson and Cathcart (1954), and the Pablo does not contain siliceous lavas. Foliated rhyolitic rocks that intrude the Pablo as well as other pre-Darrough units in Jett, Pablo, and upper Peavine Canyons are here assumed to be segments of the Tertiary dike system of Jett Canyon.

TUFFACEOUS ROCKS OF THE DARROUGH FELSITE

Tuffaceous rocks of the Darrough Felsite include three chief intergradational types, here called crystal-tuff breccia, crystal-lithic tuff, and distinctly laminated crystal tuff. All contain between 20 and 60 percent crystals and average about 40 percent. The crystal assemblage is rather uniform in the specimens examined. Quartz, at places highly resorbed, is generally more abundant than K-feldspar or plagioclase, which are in generally equal proportions. K-feldspar has $2V \approx 25°$ and about 12 percent K_2O (average of two analyses), indicating it is sanidine; plagioclase is mildly zoned and has compositions estimated at An_{10} to An_{20}. The albite is probably in large part modified to its present composition by hydrothermal alteration. Sparse, coarse biotite flakes are widespread but rare and hornblende phenocrysts occur at a few places. In most specimens, the feldspar phenocrysts appear fresh, whereas the mafic minerals are variably altered. The crystal mode implies that the tuffs are rhyolite to quartz latite or rhyodacite. The matrix of the tuff which was once shards is now uniformly crystallized or devitrified and is a dense microcystalline intergrowth of quartz, K-feldspar, and plagioclase. X-ray diffraction analysis of the matrix suggests that the quartz content exceeds that of feldspar by a factor of 3 or more. Very fine grained secondary brown biotite occurs in crystal tuffs at a few places along certain foliae, enhancing the already conspicuous foliation. Thin veinlets of epidote and chlorite that cut the foliation are scattered throughout the Darrough Felsite. The tuff also contains a widely varying quantity of lithic fragments whose diameters are generally less than 10 cm and mostly a centimetre or less. The clast types are aphanitic felsic igneous rocks, granitic rocks, chert, slate, quartzite, marble, gray limestone, laminated calcareous siltstone-mudstone, and calc-silicate and pelitic hornfels. The fine-grained igneous clasts are much like the crystal tuff of the Darrough Felsite except that the phenocryst content is lower and the foliation less well developed in the clasts. The clasts of sedimentary and metasedimentary rocks can all be related to rocks in various pre-Tertiary units in the area of figure 1.

The crystal-tuff breccias contain such a high proportion of lithic clasts that the crystals and clasts in effect constitute a rigid particle framework. The framework evolved in some samples by moderate compaction and welding, and in others, it existed at the time of emplacement by tight grain packing. Relics of devitrified undeformed shards occur abundantly in the framework interstices. Some pumice blocks and lapilli in tuff breccia are squashed, but where they exist between rigid particles, pumice lapilli are relatively undeformed. Foliation in the tuff breccia is defined by the elongation of occasional collapsed pumice clasts. Welding of some degree is apparent in some of the crystal-tuff breccias.

The term "crystal-lithic tuff" is used for rocks in which crystals and lithic fragments are largely suspended in ash, shards, and pumice, all of which are now completely welded and devitrified. Lithic clasts are less plentiful in this rock type than in the tuff breccia. Relict shard textures in most of the crystal-lithic tuffs show that the tuffs are highly compacted, but they are locally less deformed where protected within clots of rigid particles. The pumice clasts are moderately to strongly compacted. The foliation in the crystal-lithic tuff is subtly to conspicuously eutaxitic. The foliations usually diverge symmetrically about rigid particles, indicating axial compaction. Structures indicating particle rotation are infrequent.

The laminated crystal tuff (fig. 2) contains few, if any, lithic clasts, and it represents the minimum ratio of rigid particles to matrix of the tuffaceous rocks of the Darrough Felsite. The apparent inverse relation of degree of compaction and proportion of rigid particles in the tuffaceous rocks suggests that the laminated crystal tuffs represent the most easily compacted members of a series of tuffaceous rocks that were all subjected to similar compaction loads. This rock type is characterized by nearly continuous lamination that is conspicuous compared to the foliations in the tuff breccias or crystal-lithic tuffs. The lamination is defined by grain size variations in the devitrified quartzofeldspathic microlite matrix and by rare local concentrations of secondary biotite. Rarely, some laminae are lenticular and contain internal coplanar streaks. Such features suggest that the laminae may be collapsed pumice lapilli, at least in part, and provide textural evidence of a pyroclastic origin. Such rocks are thought to be totally compacted and welded tuff, and their laminations may have formed by viscous flow after compaction. Recumbent folds, monoclinic divergence of the foliation about some crystals, and occasional ramp structures indicate that flowage occurred at places in the laminated crystal tuffs (Walker and Swanson, 1968).

A striking feature of the tuffs of the Darrough Felsite is their uniform toughness and apparent lack of porosity. Microscopic observations indicate that porosity is lacking regardless of the primary type of tuffaceous rock or the degree of deformation of relict shards

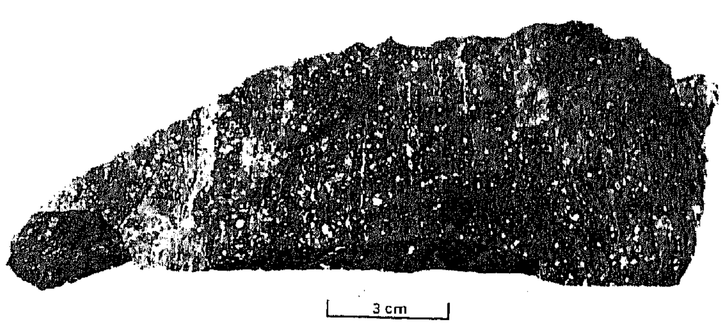

FIGURE 2.—Laminated crystal tuff from area of localities 1, 2, and 3 in figure 1.

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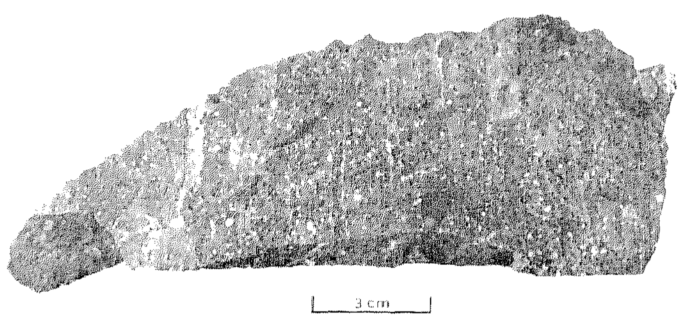

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and pumice. Bulk density measurements of eight tuffs of the Darrough are between 2.56 and 2.70 g/cm^3, and the average is 2.64 g/cm^3. The densities indicate that these quartzofeldspathic rocks can contain no pore space, and density measurements during water immersion for 24 h are constant. Textures imply, however, that compaction of the Darrough Felsite cannot alone have produced the apparent lack of porosity, and we suggest that pervasive silicification in the form of deposition of quartz or quartzofeldspathic minerals from through-going fluids was a major contributing factor. Microcrystalline quartz dominates the matrix of the tuffaceous rocks, and the proportion of matrix quartz is greater than one would predict from the phenocryst assemblage of a rhyolite to rhyodacitic melt. The association of equal amounts of sanidine and albite, which equilibrate only at relatively low temperatures, also suggests modification by hydrothermal solutions or low-grade metamorphism. This interpretation suggests that precipitation in pores was contemporaneous with devitrification and replacement of shards and pumice because such originally glassy fragments are not obviously mineralogically different from the rest of the matrix. Reconnaissance of the Darrough Felsite has not revealed any clear sequence of cooling units or a typical compaction zonation. Such phenomena may be absent, or they may simply be difficult to recognize in the field because of the general uniformity of lithology or pervasive chemical changes in the volcanic pile.

BRECCIA AND SEDIMENTARY ROCKS

Intercalated with the tuffs in the Darrough Felsite are layers of massive and locally bedded fragmental rocks. Some massive breccias consist of unsorted accumulations of sedimentary and metasedimentary rock fragments as much as a metre in diameter set in a matrix of fine- to medium-grained feldspar-quartz-lithic sandstone. Other breccias differ by containing fragments chiefly of aphanitic igneous rock types, probably derived from the Darrough Felsite itself. The breccias in general appear to constitute various mixtures of crystals, lithic clasts, and probably ash from the Darrough with lithic debris from the nonvolcanic terrane that forms the basement in the region. Volumetrically small bodies of rocks associated with the breccias consist of moderately sorted sand-and-pea-gravel-sized particles in beds and laminations with a thickness of a metre or so.

AGE OF THE DARROUGH FELSITE

An age for the Darrough Felsite is established from several observations, the first of which is that the deformation of the Darough is slight compared to that of pre-Tertiary rocks in the area. The base of the Darrough at North Twin River is nearly planar and truncates folded pre-Tertiary formations and contacts. Darrough Felsite was emplaced after the last penetrative deformation of the Pablo Formation, which was probably in Jurassic time or perhaps even later. At the least, the deformational contrast between the Darrough and the Pablo indicates the two units are not coeval.

The Darrough Felsite is also younger than the Ophir pluton, whose age is a minimum of about 54 m.y. In the vicinity of North Twin River and South Twin River, the Paleozoic rocks are strongly metamorphosed by the Ophir pluton, but unmetamorphosed Darrough Felsite contacts the hornfels around the pluton although it crops out within a few tens of metres of this granitic body. The absence of significant recrystallization of the cryptocrystalline quartzofeldspathic matrix of the Darrough Felsite at North Twin River contrasts markedly with the strong metamorphism of the Paleozoic rocks. Also, the basal part of the Darrough Felsite here contains abundant fragments of granitic rocks, possibly from the Ophir pluton, and clasts of hornfels whose degree of recrystallization contrasts sharply with that of the Darrough matrix.

K-Ar ages on mineral separates from the Darrough Felsite and from associated rocks (table 1) suggest that the Darrough is most likely middle Tertiary in age. It should be noted, however, that all the ages from the Darrough, as well as most of the dates on rocks that might shed light on the age of the formation, are ambiguous in the light of geologic relations and when compared with other dated rocks in central Nevada.

The Ophir pluton, which appears older than the Darrough Felsite on the basis of metamorphic relations, yields an apparent age (but most likely not the crystallization age) of about 54 m.y. (No. 6, table 1) and serves as a lower limit for the age of the Darrough. Ash-flow tuff of the tuff and breccia unit that lies on top of the Darrough has an age of 22.7 m.y. (No. 4, table 1) which is considered a minimum age for the Darrough.

Age determinations on the Darrough Felsite itself include two analyses on different sanidine separates from the same specimen that are 22.3 ± 0.8 m.y. and 22.7 ± 0.8 m.y. (Nos. 1 and 2, table 1) and hornblende from a second sample (No. 3, table 1) that yields an age of 26.7 ± 1.0 m.y. This spread may represent real differences in age between different parts of the felsite body, or the younger sanidine age may reflect some postemplacement heating or alteration event.

An age of 29.4±0.8 m.y. on biotite (No. 5, table 1) from quartz monzonite porphyry of the Jett Canyon dike system that cuts the Darrough Felsite suggests that the Darrough may be older than the 22–27-m.y. age of the minerals from the body itself. The 29.4-m.y. age, however, is here considered less reliable than the ages obtained directly on the Darrough, and, considering the contact relations of units, is probably anomalously old.

Considering all the dates, the geologic relations, and the nature of the Darrough and nearby rocks, a middle Tertiary age seems warranted for the Darrough Felsite.

DIKES ASSOCIATED WITH THE DARROUGH FELSITE

On the north side of the Darrough Felsite in the area of figure 1, dikes of siliceous igneous rocks like those of the Jett Canyon system cut pre-Tertiary rocks, and in particular they intrude faults in the vicinity of the Darrough contact. North of the Twin River drainage, siliceous dikes are sparse, suggesting as in Jett Canyon that dikes are concentrated near the margin of the Darrough Felsite.

Reconnaissance indicates that the substrate to the Darrough Felsite is strongly faulted and intruded by dikes that are of similar composition to the Darrough. In addition many dikes contain lithic fragments similar to those in the pyroclastic parts of the overlying felsite. Because stratigraphic relations and radiometric ages indicate that the dike system, at least in Jett Canyon, is penecontemporaneous with the Darrough Felsite, we suggest that the dike system was the plumbing through which magmas of the Darrough Felsite were transferred from depth.

ORIGIN OF THE DARROUGH FELSITE

The Darrough Felsite is a thick, areally restricted accumulation of crystal-rich pyroclastic rocks and epiclastic beds that were deposited as a succession of ash and breccia flows. The thick tuff accumulation is interpreted to lie above and perhaps adjacent to its feeder system and is intruded by such feeders. The thickness of tuff suggests deposition in a topographic depression, and the abundance of faults in the Darrough substrate associated with the inferred feeder dike system suggests that structural subsidence was related to eruption of the tuffs.

The high degree of compaction of the laminated crystal tuffs suggests that the material accumulated rapidly so that little heat was lost between ash flows and the entire pile reached high temperatures throughout. Flow banding common in some places indicates that compaction and heating were great enough to cause local late flowage.

We suggest that the Darrough Felsite is a strongly compacted tuff pile that accumulated in a middle Tertiary volcanotectonic depression or caldera. The widespread, pervasive silicification and the alteration of this volcanic sequence contrast markedly with the features observed in other similar bodies of extrusive rock from similar volcanic centers of Tertiary age in central Nevada. The reason for these phenomena is unknown.

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