PURPOSE OF THE REPORT

The purpose of this report is to bring together pertinent tephrochronological information relative to upper Cenozoic silicic volcanic ash beds of the Western United States and to summarize this information on a chart (fig. 1). This chart comprises a composite stratigraphic summary of the known and inferred sequences of ash beds that range from 4.0 to 0.1 m.y. and that are found in Pliocene sedimentary rocks and Quaternary deposits. It is a first attempt at a stratigraphic reconstruction of data (known to the writer as of 1981) relative to ash beds and is designed to provide a provisional framework useful for those interested in chronology problems related to the upper Cenozoic. As more tephrochronological information is gathered, changes in this first version of figure 1 will undoubtedly be needed.

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ASH BED CLASSIFICATION

Most highly siliceous volcanic ash beds of the Western United States, including those described on figure 1, can be grouped into two somewhat intergradational chemical types, rhyolitic[1] and dacitic ashes.

[1]The definitions used for rhyolite and dacite in this paper are somewhat different than the definitions recently used by Ewart (1979, p. 15) for salic volcanic rocks. Ewart defined dacite as a volcanic rock that contains 63-69 percent SiO_2 and rhyolite as a volcanic rock that contains more than 69 percent SiO_2. As used in the present report, dacite can be nearly as highly siliceous as rhyolite, except dacite has more calcium and less potassium than rhyolite.

These two different ash-bed types can be distinguished based on the chemical composition of their glass shards. The main property that distinguishes dacitic from rhyolitic ashes is the greater Ca and Mg and smaller K content in glass shards of dacitic ashes compared to rhyolitic ashes. Dacitic volcanic ashes are here arbitrarily defined to have more than 0.55 weight percent Ca. Rhyolitic ashes were subdivided further into two types, W- and G-type rhyolites, based on the presence of biotite in the W-type, and its absence in G-type rhyolitic ashes. Chemical analyses of the glass shards of the ash beds on figure 1 and hundreds of other vitric Tertiary ashes and tuffs show that nearly all W-type rhyolitic ashes have Fe and Ca contents less than 0.55 weight percent. Ca and Fe were chosen to group the volcanic ashes on figure 1 because they are elements that show fairly large weight-percent variation in comparison with other major rock-forming elements.

Additional characteristics of the three ash bed types, W-type rhyolitic, G-type rhyolitic, and dacitic are given in the discussion that follows.

W-type rhyolitic ashes (1) are chalky white megascopically, (2) have less than 0.55 weight-percent Fe and less than 0.55 weight-percent Ca in the glass shards, (3) always have phenocrystic biotite and lack fayalite, (4) characteristically have a large percentage of microscopically colorless glass shards of pumiceous habit whose indices of refraction generally range from 1.494 to 1.497, (5) have a low percentage of glass shards that contain microlites, (6) generally have microphenocrysts of quartz, sanidine (soda poor), plagioclase (oligoclase), clinopyroxene, hornblende, magnetite, ilmenite, apatite, and allanite (mineral species that occur in a few rhyolitic ash beds include orthopyroxene and sphene), (7) generally have SiO_2 contents of the glass shards (corrected volatile-free) from 76 to 79 percent, and (8) have glass shards with narrow compositional ranges for the major rock-forming elements.

G-type rhyolitic ashes (1) are light to medium gray megascopically, (2) have from 0.55 to 2.0 weight-percent Fe and less than 0.55 weight-percent Ca in the glass shards (some upper Cenozoic, G-type rhyolitic ashes, but none shown on figure 1, have as much as 2.5 weight-percent Fe in glass shards), (3) lack phenocrystic biotite, (4) mainly have colorless (microscopically), platy bubble-wall and bubble-junction glass shards whose indices of refraction range from 1.497 to 1.520, (5) generally lack glass shards that contain microlites, (6) have a microphenocryst assemblage that generally includes sanidine (soda rich), sodic plagioclase (oligoclase), clinopyroxene and hornblende (Fe-rich varieties in some instances), fayalite, magnetite, ilmenite, apatite, allanite, and chevkinite, (7) generally have SiO_2 contents of the glass shards (corrected volatile-free) of from 72 to 79 percent and, (8) have glass shards with narrow compositional ranges for the major rock-forming elements.

Dacitic ashes (1) are white to light gray or light grayish brown megascopically, (2) have more than 0.55 weight-percent Fe and Ca in the glass shards, (3) have a complex mixture of shard shapes, including pumiceous, fibrous, chunky, and bubble-wall and bubble-junction types, (4) have indices of refraction of glass shards that range widely from 1.496 to 1.530, (5) commonly contain appreciable numbers of brown glass shards compared to the numbers of colorless glass shards, (6) commonly contain glass shards charged with ferromagnesian mineral and feldspar microlites, (7) frequently lack phenocrystic quartz, sanidine, and biotite, but have a microphenocryst suite that may contain plagioclase (typically andesine), clinopyroxene, orthopyroxene, amphibole (hornblende and cummingtonite), magnetite, ilmenite, and apatite, (8) generally have SiO_2 contents of glass shards that are less than the SiO_2 contents in W- and G-type rhyolitic ashes and that range from 67 to 77 percent, and (9) have glass shards that have wide compositional ranges for the major rock-forming elements.

In summary, the chief chemical property that distinguishes the rhyolitic ash beds from the dacitic ash beds of figure 1 is the greater Ca content in the glass shards of the dacitic ashes. Of nearly equal importance is the lower K and higher Mg content of the glass shards of dacitic ashes compared with rhyolitic ashes. In addition, dacitic volcanic ashes frequently lack quartz and sanidine microphenocrysts.

The most important property that distinguishes W-type from G-type rhyolitic ash beds is the ubiquitous content of biotite in W-type rhyolitic ashes. Of secondary importance is the general lack of fayalite in W-type rhyolitic ashes.

The geologic setting in which most W- and G-type rhyolitic magma systems, including the Long Valley, Yellowstone National Park, and Jemez Mountains, were generated is in areas underlain by continental crust undergoing extensional tectonics. The geologic setting in which most dacitic ash beds were generated is chiefly in areas near active continental-oceanic plate convergence such as the Cascade Mountains region of the Pacific Northwest.

MINERALOGY OF ASH BEDS

Primary crystals in volcanic ash beds generally can be distinguished from detrital minerals incorporated in ashes during deposition by the presence of glass coatings, crusts, or mantles on the primary microphenocrysts and the absence of glass coatings on detrital minerals. During study of volcanic ashes, application of the glass-mantle criteria (see Wilcox, 1965, p. 813) must be strictly invoked to insure that the primary mineral assemblage of volcanic ashes, which is used to characterize a certain ash, is correctly compiled.

The primary minerals of volcanic ash beds are generally small euhedral crystals and broken crystals that grew just prior to the time of vesiculation and quenching of a magma. The amount of crystals in pumice blocks found in volcanic source areas is small, generally less than 25 percent. In contrast, the amount of primary crystals in ash beds far downwind from their source areas is typically far less than one percent.

The primary microphenocrysts found in volcanic ash beds, and in particular the volcanic ash beds on figure 1, comprise assemblages of the following minerals: quartz, sanidine, sodic-plagioclase, biotite, amphibole, clinopyroxene, orthopyroxene, fayalite, zircon, apatite, allanite, chevkinite, sphene, magnetite, and ilmenite. Study of hundreds of samples of volcanic ash beds of Oligocene to Holocene age from the Western Interior by the author shows that they also may contain the above-listed minerals as well as perrierite and monazite. Most ash beds contain only one compositional type of each of the above listed minerals. An exception to this observation is that certain ashes derived from some Cascade volcanoes contain two kinds of amphibole—common hornblende and cummingtonite.

Some primary minerals of those listed above show a preference for one of the three ash-bed types. Fayalite and chevkinite have been found only in G-type rhyolitic ash beds. Biotite, sphene, monazite, and perrierite have only been found in W-type rhyolitic ash beds. High-temperature beta quartz and sanidine nearly always constitute the chief microphenocrysts of W- and G-type rhyolitic ashes, but they rarely are found in dacitic ash beds. Zircon typically resides in rhyolitic ash beds and is not common in dacitic ash beds. Although small amounts of allanite and apatite are present in some G-type rhyolitic ash beds, they are pervasive members of the accessory mineral suite of most W-type rhyolitic ash beds. Apatite typically occurs in dacitic ash beds.

Glass-mantled primary microphenocrysts of garnet, anorthoclase, and sodic-amphibole and sodic-clinopyroxene have not been found by the writer in volcanic ash beds of the Western United States, although these minerals are reported to occur in some ash-flow tuffs. Garnet, for example, is found in some ash-flow tuffs, but, in the writers experience, it always is a vapor-phase crystallization mineral.

CHEMICAL COMPOSITION OF ASH BEDS

For the past several decades, chemical composition has been used extensively to fingerprint or characterize volcanic ash beds for correlation by Swineford and Frye (1946), Powers and others (1958), Powers and Malde (1961), Jack and Carmichael (1968), Theisen and others (1968), Smith and Westgate (1969), Borchardt (1970), Izett and others (1970), Borchardt and Harward (1971), Borchardt and others (1972), Izett and others (1972), Sarna-Wojcicki (1976), Nash and Smith (1977), Sarna-Wojcicki and others (1979), and Sarna-Wojcicki and others (1980).

Partial chemical analyses of the glass shards for most of the ash beds are shown on figure 1. Considerably more chemical data for the ash beds shown on figure 1 are available, but only a condensed array of chemical data is presented here. Differences and similarities in chemical composition among some of the ash beds are tabulated on figure 1.

The values for the amounts of the elements listed on figure 1 were rounded by the writer from the values determined from analyses of the ashes. The amount of Ca, Fe, and Ti was rounded to the nearest hundredth of a weight percent; the amount of Hf, Ta, and U was rounded to the nearest tenth of a part per million; and the amount of Mn, Rb, and Zn was rounded to the nearest 5 parts per million (ppm).

Analyses shown on figure 1 for Fe, Hf, Mn, Rb, Ta, and U were made by instrumental neutron activation methods by H. T. Millard, Jr., and R. J. Knight of the U.S. Geological Survey. Analyses for Ca and Zn (by atomic absorption photospectrometric methods) and for Ti (by colorimetric methods) were made by V. M. Merritt and G. T. Burrow of the U.S. Geological Survey. The symbol ND is shown on figure 1 when analytical data are not now available for an ash bed.

The composition of the glass shards of the volcanic ash beds listed on figure 1 are highly siliceous in that their Si content ranges from about 67 to 79 weight-percent SiO_2 (calculated volatile free). Most of the rhyolitic ashes are highly evolved types that contain from about 74 to 79 weight-percent SiO_2, calculated volatile-free. The dacitic ashes on figure 1 vary from about 67 to as much as 77 weight-percent SiO_2; the Al content ranges from about 10.5 to 14.5 weight-percent Al_2O_3. In general, the G-type rhyolitic ashes have the lowest Al content and the dacitic ashes have the highest content of Al. The Mg content is low in the rhyolitic ashes (as little as 0.06 weight-percent MgO) and is considerably higher in dacitic ashes (1.0 weight-percent MgO). The dacitic ashes have the highest Fe content in the glass shards (expressed as Fe_3O_4) ranging from about 0.80 to 3.8 weight percent. The rhyolitic ashes have the lowest amounts of Fe expressed as Fe_3O_4 (0.5–1.9 weight percent). Ca ranges from an unusually low amount (0.25 CaO weight percent) in ashes derived from the Jemez Mountains area (especially beds in beds 27 and 18) to as much as 2.2 weight-percent CaO in dacitic ashes derived from the Cascade volcanic province.

All the glass shards of the ashes listed on figure 1 are hydrated (as are all other ash beds of the upper Cenozoic) and some contain as much as 4.5 weight percent H_2O. The original amounts of Na and K in the glass shards of the ashes, as they were erupted, cannot be accurately determined because of cation exchange between ground water and the glasses during hydration (Lipman, 1965). In general, Na is lost and K is gained, and this diagenetic change probably accounts for much of the differences in Na and K content of the Mesa Falls (bed 22 of fig. 1) and Lava Creek B ashes (bed 11 of fig. 1).

W-type rhyolitic ashes were probably peraluminous to metaluminous when erupted, and G-type rhyolitic ashes were probably subaluminous to peralkaline. However, the original content of the alkali elements K and Na, relative to Al, in the glass shards of the ashes as erupted cannot be determined as suggested above.

PALEOMAGNETIC REVERSAL SEQUENCE

The paleomagnetic reversal sequence shown on figure 1 follows that published by Mankinen and Dalrymple (1979). To calculate ages for their accompanying time scale, they used atomic abundances and decay constants recommended by the International Union of Geological Sciences (Steiger and Jager, 1977). The measured paleomagnetic polarity (DRM) of most of the ash beds shown on figure 1 were in most instances determined by either the writer, by J. G. Honey, or by J. J. Dickson, all of the U.S. Geological Survey. J. W. Hillhouse (oral commun., 1978) of the U.S. Geological Survey determined the paleomagnetic direction of ash bed 6 of figure 1.

BOUNDARY BETWEEN THE PLIOCENE AND PLEISTOCENE

The boundary between the Pliocene and Pleistocene used on figure 1 is 1.8 m.y. old as suggested by isotopic age studies done in the continuous marine Pliocene and Pleistocene sequence in the stratotype area of southern Italy, near the Vrica section about 4 km south of Crotone, Calabria. The Vrica section has been proposed as a Pliocene and Pleistocene boundary stratotype (Selli and others, 1977). They (p. 195) reported a fission-track age of 2.07±0.33 m.y. (corrected for fission-track annealing) measured on glass shards from an ash bed, m marker bed, at the inferred Pliocene and Pleistocene boundary at the Vrica section. The m bed is near the stratigraphic level at which fossils are found that suggest climatic deterioration (cooling) in the Mediterranean Sea and accordingly marks the beginning of Pleistocene time. In addition, Selli and others (1977, p. 194), reported a K-Ar age of 2.2±0.2 m.y. measured on glass shards that were separated from the m ash bed at the Pliocene and Pleistocene boundary at the Vrica section. They also reported a K-Ar glass age of 2.0±0.1 m.y. measured on glass separated from a sample of a large pumice block (found by quarry workers in the southern part of the city of Crotone) at a level thought to correlate with the marker horizon at the Vrica section (G. Bigazzi and G. Pasini, oral commun., 1979). The m marker bed also was dated by Boellstorff (1978) who reported a fission-track age of 2.5±0.1 m.y. measured on glass (uncorrected for fission track annealing).

The ash dated by G. Bigazzi and reported in Selli and others (1977) is apparently not the m marker bed, but an ash that lies 300 m stratigraphically below the m bed (C. W. Naeser and G. Bigazzi, written commun., 1980). The index of refraction of glass shards and the mineralogy of a split of the sample dated by Bigazzi (in Selli and others 1977) do not match samples of the m marker bed collected by C. W. Naeser, J. D. Obradovich, and G. A. Izett. These properties, however, do match the properties of the ash that lies 300 m below the m bed in the Vrica area. Seemingly, samples of the m ash bed and the ash bed that occurs 300 m below were inadvertently switched in the laboratory or in the field at the time the samples were collected.

Until precise K-Ar ages are determined on minerals rather than on glass of the ashes at the Vrica section (work in progress by C. W. Naeser, J. D. Obradovich, and G. A. Izett), the precise age of the Pliocene and Pleistocene boundary at Vrica remains uncertain. Preliminary K-Ar (mineral) and fission-track (zircon) ages from the ash bed that occurs about 300 m below the m marker bed indicate that the Pliocene and Pleistocene boundary of Selli and others (1977), at the Vrica section near Crotone, Italy, is considerably younger than 2.1 m.y. and is arbitrarily placed on figure 1 at 1.8 m.y.

RANGE ZONES OF CERTAIN LARGE FOSSIL MAMMALS

The range zones of certain fossil mammals commonly found in nonmarine sedimentary rocks of the Western Interior (fig. 1) include the elephant, Mammuthus (Irvingtonian and Rancholabrean); the mastodon, Stegomastodon (Blancan); the zebra, Equus (Dolichohippus) (Blancan); and the horse Equus (Equus) (Irvingtonian and Rancholabrean). The range zones are based on reported occurrences of the above fossils in Pliocene and Pleistocene deposits of the Western Interior and from unpublished data from fossil mammal collections made near the Blancan and Irvingtonian transition in Kansas and Texas by the writer and J. G. Honey.

ASH-BED NUMBER

Ash beds were assigned numbers only to facilitate descriptions in the text and to show stratigraphic relations among ash beds of figure 1; these numbers have no other significance.

ASH BED NAME

The informal naming of volcanic ash beds is a long-accepted practice in American geology as evidenced by the use of such names as the "Pearlette ash" (Cragin, 1896, p. 54). Since that time, many other ash beds and bentonite beds (altered volcanic ash beds) have been named in either an informal, or in some instances, a formal sense. Some examples of formally named ash beds are (1) the Pearlette Ash Member of the Sappa Formation (Flint, 1955, p. 41-54) (2) the Pearlette ash lentil of the Atwater Member of the Crooked Creek Formation (Hibbard, 1958, p. 55-57) and, (3) the Pedro Bentonite Bed (Ardmore Bentonite Bed of current usage) of the Mitten Black Shale Member of the Pierre Shale (Mapel and Pillmore, 1963). Either formal or informal usage is acceptable as outlined in the Code of Stratigraphic Nomenclature, Article 8 (a,b) (American Commission on Stratigraphic Nomenclature, 1970). However, the informal naming of ash beds can lead to a complex nomenclature if scattered volcanic ash deposits, which are remnants of a single, formerly extensive ash blanket generated during a brief, intense volcanic eruption, are each given a different name. Thus, an unnecessarily complex nomenclature could result in considerable confusion for those not acquainted with the latest nomenclature changes and additions. Another practice used, which should be discouraged, is the proposal of a new name for an ash bed using evidence only from isotopic age data and ignoring other tephrochronologic data. Because a bed of volcanic ash has a slightly different isotopic age than other ash beds with which it certainly correlates, based on abundant mineralogical and chemical data, is a poor reason to assign it a new ash-bed name.

The nomenclature system used for naming many of the previously unnamed ash beds listed on figure 1, and the one currently used by many tephrochronologists, is to name an ash bed informally for its source-area rock unit, if known, or to name it informally for its principal geographic occurrence, if the source area and rock unit are not known. In a few instances, ash bed names used on figure 1 were named previously by geologists for (1) a person, by Yeats and McLaughlin in 1970 (Bailey ash, bed 19, for T. L. Bailey) and (2) a petrographic feature by Malde in 1972 (Upper Lapilli, bed 60 and Lower Lapilli, bed 67, for their coarse-grained, pumiceous shard habit).

All ash beds that clearly correlate with a previously named ash bed should be assigned the same name. An example of this practice is the naming of the Peters Gulch ash bed (bed 65, fig. 1) for its occurrence at Peters Gulch near Hagerman, Idaho (Powers and Malde, 1961). If more occurrences of the Peters Gulch ash bed are found, they also should be called the Peters Gulch ash.

If enough tephrochronologic data are available to correlate an ash bed, with a high probability, with its source-area rock unit the ash bed is given the source-area rock unit name in order to avoid duplication of names and to establish its genetic relation with a source-area rock unit. An example of this practice was the informal naming of the Bishop ash bed (bed 13, fig. 1) the Western United States (Izett and others, 1970) for its source-area rock unit, the Bishop Tuff of eastern California. In some instances, an ash bed was informally named and correlated to a formally named source-area rock unit of bed rank. An example (Izett and others, 1972) of this situation was the informal naming of the Guaje ash bed (bed 27, fig. 1) of the southern Great Plains for its source-area rock unit, the Guaje Pumice Bed of the Otowi Member of the the Bandelier Tuff of north-central New Mexico.

Applying the above nomenclatural principles, several new names for ash beds are introduced on figure 1 and are named for either geographic localities or for source-area rock units. In particular, new names for the Pearlette ash beds type B, type S, and type O of Izett and others (1970) and of Naeser and others (1973) are here used, based on the high probability of their correlation with formally named pyroclastic source-area rock units in the Yellowstone National Park area of Wyoming and Idaho. The Pearlette type B ash was named the Huckleberry Ridge ash bed (bed 36, fig. 1) by Izett and Wilcox (1981) for its equivalent source-area rock unit, the Huckleberry Ridge Tuff of Christiansen and Blank (1972, p. 3-4). The Pearlette type S ash bed was named the Mesa Falls ash bed (bed 22, fig. 1) by Izett and Wilcox (1981) for its equivalent source-area rock unit, the Mesa Falls Tuff of Christiansen and Blank (1972, p. 5-6). The Pearlette type O ash bed was named (Izett and Wilcox, 1981) the Lava Creek B ash bed (bed 11, fig. 1) for its equivalent source-area rock unit, the Lava Creek Tuff, member B of Christiansen and Blank (1974a). A newly adopted unit of the Pearlette family of ash beds was named the Lava Creek A ash bed (bed 12, fig. 1) by Izett and Wilcox (1981), and it was named for its equivalent source-area rock unit, the Lava Creek Tuff, member A of Christiansen and Blank (1974a). Lava Creek A ash bed underlies Lava Creek B ash bed in Wyoming, and recognition of Lava Creek A ash bed is based on significant mineralogical and chemical differences between the two units. These differences include (1) much greater proportion of hornblende and allanite in Lava Creek A ash than in Lava Creek B, (2) lack of clinopyroxene and ilmenite in Lava Creek A and its presence in Lava Creek B ashes, (3) the pumiceous shard habit of Lava Creek A ash compared to the platy, bubble-wall shard habit of Lava Creek B, and (4) significantly less iron and more uranium in the glass shards of Lava Creek A compared with Lava Creek B ashes. The nomenclature changes made by Izett and Wilcox (1981) for Pearlette family ash beds was based on a large amount of mineralogical and chemical data that relate downwind ash beds to their source-area tephra units (Izett and others, 1970; Izett and others, 1972; Naeser and others, 1973; G. A. Izett, unpublished data, 1980).

The name Pearlette ash was retained by Izett and Wilcox (1981) as an informal name to be used in a broad sense when not enough chemical, mineralogical, and petrographical data are available to specifically identify the ash as either Huckleberry Ridge, Mesa Falls, Lava Creek A, or Lava Creek B ash.

STRATIGRAPHIC RELATIONSHIPS

The stratigraphic relationships among the various ash beds are shown on figure 1. Information concerning localities at which the superposition of several ash beds can be demonstrated is given in the section at the end of the report that describes the principal occurrences of the ash beds.

SOURCE-AREA ROCK UNIT AND SOURCE AREA

The source-area, rock-unit name and the source area of the ash beds are listed on figure 1 for those beds that have sufficent chemical and mineralogical information available to reasonably establish their correlations with their suspected source-area pyroclastic equivalents. In addition, the source areas of some of the other ash beds on figure 1 are inferred using their chemical and mineralogical similarities with ash beds of known source areas.

Numerous volcanic ash beds have been found in sedimentary deposits far downwind from the three largest, rhyolite volcanic centers of the Western United States, including the Yellowstone National Park area of Idaho and Wyoming, the Long Valley-Glass Mountain area north of Bishop, Calif., and the Jemez Mountain area of north-central New Mexico (Izett and others, 1970; Izett and others, 1972; Izett, Obradovich, Naeser, and Cebula, 1978). These ash beds can be correlated with plinian, air-fall pumice deposits that underlie the largest, caldera-forming pyroclastic flows in the aforementioned source areas. In addition, ash beds are currently being found and correlated with small-volume rhyolitic, pyroclastic units that were generated prior to or following the emplacement of the large pyroclastic flows in the three large rhyolite volcanic centers. However, downwind volcanic ash beds have not been certainly identified from some of the small volcanic fields of the Western United States that generated small-volume, silicic pyroclastic flows and related plinian pumice falls such as the Clear Lake volcanic field of northern California (Hearn and others, 1976), the Coso volcanic field of east-central California (Duffield and others, 1980), the Mount Taylor volcanic field of New Mexico (Lipman and Mehnert, 1979, p. B3), and the San Francisco Peaks volcanic field of Arizona (Sheridan and Updike, 1975). Downwind volcanic ash beds from these and other small-volume, silicic volcanic centers will almost certainly be found in the future.

ISOTOPIC AGE

Published isotopic ages and their source references for some ash beds and tuffs are shown on figure 1 as are several previously unreported isotopic ages. Potassium-argon (K-Ar) age data for the previously unreported ages on figure 1 are given on table 1, and the previously unreported, fission-track (FT) age data are given on table 2. Potassium-argon ages of glass shards have been determined for some of the ash beds and tuffs, but they are not listed because of their unreliability (Curtis, 1966; Izett and others, 1978; Naeser and others, 1980). Fission-track ages measured on glass shards of volcanic ash beds have been used by others to date upper Cenozoic beds, but are not used for age control on figure 1. Fission-track ages of glass shards from upper Cenozoic ash and tuff beds are generally younger than the zircon fission-track ages from the same beds; the tendency for fission-track glass ages to be younger than zircon crystals from the same beds results from the well-established fact of track fading or annealing in the glass shards of the beds during geologic time (see Lakatos and Miller, 1972; Storzer and Poupeau, 1973; Naeser and others, 1980). Most of the K-Ar ages on figure 1 were calculated using isotope concentrations and decay constants recommended by the International Union of Geological Sciences (see Steiger and Jager, 1977). Fission-track ages were calculated using a decay constant (λ_f) for the spontaneous decay of ^{238}U of $7.03X10^{-17} yr^{-1}$.

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Table 1.--K-Ar ages of certain ash beds and tephra units of figure 1 for which analytical data previously have not been reported
[Argon isotope analyses by G. A. Izett, J. D. Obradovich, and H. H. Mehnert; potassium determined by flame photometry by V. Merritt; decay constants used: $^{40}K/K_{total}= 1.167x10^{-4}$; $g_e+g_{e'}= 0.581x10^{-10} yr^{-1}$; $g_b= 4.962x10^{-10} yr^{-1}$; ± is one sigma]

Ash bed No. from fig. 1	Lab No.	K_2O (in percent)	Sample weight (in grams)	Radiogenic ^{40}Ar (in moles/g)	Radiogenic ^{40}Ar (in percent)	Age x 10^6 (in years)	Sample No.	Sample location
10	DKA 3809	10.64	7.561	$8.477x10^{-12}$	72.4	0.55±0.01 sanidine	78G175	Pumice lapilli from pumice pits at the Pumice Hole Mine in the NW1/4NE1/4 sec. 2, T. 28 S., R. 9 W., Adamsville 15-minute quadrangle, Beaver County, Utah; collector G. A. Izett.
16	DKA 3811	10.30	8.633	$1.576x10^{-11}$	91.4	1.06±0.01 sanidine	79G12	Pumice blocks from pumice pit in the NE1/4NE1/4 sec. 23, T. 2 S., R. 31 E., Glass Mountain 15-minute quadrangle, Mono County, Calif.; collectors G. A. Izett, J. G. Honey, and G. T. Cebula.
37	DKA 3808	9.43	2.755	$2.859x10^{-11}$	82.6	2.10±0.02 sanidine	79G10	Pumice lapilli from the uppermost unit of air-fall tephra at the Cowan Mine in the NW1/4NE1/4 sec. 23, T. 2 S., R. 31 E., Glass Mountain 15-minute quadrangle, Mono County, Calif.; collectors G. A. Izett, J. G. Honey, and G. T. Cebula.

Table 2.--Fission-track ages of zircon microphenocrysts of ash beds listed on figure 1 for which analytical data previously have not been reported
[Fission track analysts for ash beds: No. 13, N. D. Briggs; Nos. 12, 24, and 26, C. W. Naeser; No. 36, J. J. Dickson; Nos. 51 and 52, G. A. Izett; (504) number of tracks counted shown in parentheses; t, track; Ps, spontaneous track density; Pi, induced track density; F, neutron fluence; n, neutron; leaders(---) indicate no sample or laboratory number assigned; ± is 2 sigma; $\lambda_f=7.03x10^{-17} yr^{-1}$]

Ash bed No. from fig. 1	Lab No.	Sample No.	Ps X10^5 (in t/cm^2)	Pi X10^6 (in t/cm^2)	F X10^{15} (in n/cm^2)	Age X10^6 (in years)
14	DF 928	Ar-SP	15.9 (257)	14.40 (1167)	0.122	0.80±0.10
15	DF 2733	---	1.17 (15)	7.86 (504)	.946	.84±0.42
28	---	OJD-67-4	1.31 (20)	5.38 (411)	1.02	1.48±0.56
41	---	OJD-67-17	3.64 (32)	9.55 (420)	.958	2.20±0.3
46	---	79W211	2.95 (60)	7.39 (1598)	.976	2.32±0.15
64	DF 652	73W66	8.20 (88)	15.4 (1650)	1.11	3.53±0.68
65	DF 3050	60M59	19.3 (219)	9.13 (1034)	.296	3.75±0.36

In a few instances the isotopic age of an ash bed is apparently not exactly compatible with the plotted positions (based on stratrigraphic or other field evidence) of adjacent ash beds on figure 1 (for example, ash bed 6). However, considering the analytical uncertainty associated with the isotopic ages, the conflicts are not important.

STRATIGRAPHIC SUCCESSION, ISOTOPIC AGES, PARTIAL CHEMICAL ANALYSES, AND SOURCES OF CERTAIN SILICIC VOLCANIC ASH BEDS (4.0 to 0.1 m.y.) OF THE WESTERN UNITED STATES

By
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