FIELD GUIDE TO THE OVERLOOKS OF FISH CREEK CANYON, SUPERSTITION MOUNTAINS, PINAL COUNTY, ARIZONA

by
Charles A. Ferguson

Arizona Geological Survey
Open-file Report 05-01

January, 2005

Arizona Geological Survey
416 W. Congress, #100
Tucson, Arizona 85701

Introduction

This report is intended to be both a teaching and field guide for a spectacularly exposed sequence of silicic volcanic rocks in the northern Superstition Mountains, south-central Arizona. The sequence spans the contact between the Government Well and Tule Canyon formations as exposed along Fish Creek Canyon just south of the Salt River. The area of interest has been mapped by graduate students at Arizona State University (Malone, 1972; Suneson, 1976; Isagholian, 1983) and as part of the Arizona Geological Survey's 1997 STATEMAP program (Gilbert and Ferguson, 1997). The rocks examined are in the upper part of the 20.5Ma – 18.6Ma Superstition Group (Figure 1) which represents ~650 km^3 of intermediate to silicic lavas that were erupted prior to formation of the 350 km^2 Superstition caldera. The caldera is the source of the 18.6Ma, ~800 km^3 Apache Leap Tuff (Ferguson and Skotnicki, 1996; McIntosh and Ferguson, 1998; Ferguson and Trapp, 2001). The lack of structural complexity, remarkable exposure, general lack of alteration, and ease of access makes this one of the best areas in Arizona for examining silicic lava flows and associated pyroclastic rocks.

Purpose

Since volcanic rocks are igneous, it makes perfect sense that they should be studied in terms of how they relate to their closest relative, the plutonic igneous rock. After all, volcanic rocks are simply erupted versions of some close plutonic relative, for example; rhyolite from granite, basalt from gabbro, and andesite from tonalite. The difference is that volcanic rock, before it becomes a rock, undergoes a brief, commonly torturous period when the magma is subject to sedimentary forces. The challenge is to recognize the difference between a volcanic rock's igneous nature and its sedimentary destiny. A volcanic rock's igneous nature is characterized by its composition. Simply put, what kind of magma was it, and how many, and what kind of crystals, or phenocrysts had grown in the melt before it erupted? The phenocryst assemblage of a volcanic rock can be thought of as its genetic fingerprint. A volcanic rock's sedimentary destiny is determined by how the forces of wind, water, ice, and gravity act on it before it comes to rest, cools, and becomes a rock.

Many aspects of the study of volcanic rocks are based on information regarding the relative age of flows. Absolute dating alone cannot always provide this information, especially if time and budgetary restrictions come into play. In addition, even the most precise geochronology may not be able to discern the differences in age of volcanic rocks that were erupted in rapid succession a very long time ago. In these instances volcanic rocks need to be mapped as if they were sedimentary units, and specifically, the geologist needs to address how each unit is stratified. Pyroclastic rocks (tuffs and surges) are easy. By being blasted into tiny pieces when they erupt, the consitutents of pyroclastic rocks become in all intents and purposes sedimentary particles, and when they coalesce into a rock they obey all the physical laws that apply to sedimentary rocks. Lavas are a challenge because they are not internally stratified. Internally, lavas are layered in ways that resemble stratification, but these features, the mappable flow facies boundaries that will be described in a following section, defy the fundamental law of stratigraphy; Steno's Law of Superposition exactly 50% of the time. The only stratification within a pile of lava that consistently obeys Steno's law is the contact that bounds the individual flows. These contacts are therefore of critical importance.

Volcanic rocks as stratigraphic units

The following two definitions are from the North American Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1970). A **rock-stratigraphic unit** is a subdivsion of the rocks of the earth's crust distinguished and delimited on the basis of lithologic characteristics (an example is the Navajo Sandstone). A **time-stratigraphic unit** is a subdivision of rocks considered soley as the record of a specific interval of geologic time (an example is the Jurassic).

Sedimentary rocks make wonderful **rock-stratigraphic** units. Their utility as marker units is well known since they typically extend laterally for great distances. However, the contacts that bound sedimentary units are almost invariably time-transgressive, and in many instances the amount of time transgressed is on the order of millions of years. Volcanic rocks are also good **rock-stratigraphic** units, being easily distinguished based on distinctive petrologic characteristics. Their utility as marker units is problematic because their lateral continuity is often quite limited. However, volcanic rocks have one huge advantage over sedimentary rocks. The degree to which volcanic rock units transgress time is so insignificant (minutes or hours, and sometimes only seconds) that they are essentially **time-stratigraphic** units as well.

In recent years, the utility of the large volume (>100 km^3) ash-flow tuff sheet as a regional, laterally extensive, rock-stratigraphic, **and** time-stratigraphic unit has become widely accepted. Regional ash-flow tuffs can almost always be identified and distinguished from other flows by very specific rock-stratigraphic criteria inherited directly from its igneous nature, principally phenocryst assemblage. Failing these criteria, other tests such as palemagnetics, mineral chemistry, and geochronology can be diagnostic. Another important diagnostic feature of many regional ash-flow tuff sheets is their tendency to be vertically zoned with respect to phenocryst ratios and abundances (Ross and Smith, 1961; Smith, 1960; Smith and Bailey, 1966). This phenocryst zonation reflects the compositional variation theorized for the interior of large volume magma chambers from which ash-flow tuffs are derived (eg. Hildreth, 1979; 1981).

Like ash-flow tuffs, lava flows can usually be identified based on specific phenocryst assemblages (that igneous nature thing again), but unlike ash-flow tuffs, the phenocryst assemblage of a lava flow is rarely subject to the vertical and lateral zonations so common within ash-flow tuffs. This is because lava flows typically represent a much smaller volume of magma; at least one order of magnitude less volume of erupted material in comparison with the large-volume regional ash-flow tuff. Since lava flows represent such small volumes, it is much less likely for them to tap zones of significant compositional zonation in the parent magma chamber. Abrupt variations in the composition of individual lava flows has been recognized, but in these instances the best explanation is that magmas of vastly different composition were erupted together, possibly from discrete magma chambers, and with minimal mixing of the two types.

Once the boundaries of an individual lava flow are identified, then it may become useful to differentiate the textural variations within a flow in order to better understand how it was emplaced, and possibly to identify a vent area. These textural variations are a reflection of the volcanic rock's sedimentary destiny.

Flow-facies in lava flows

The silicic lava flow is by far the most "schizophrenic" rock on the earth's surface. A single flow may show 5 or 6 vastly different "faces" to the mapper over a short distance, and field geologists too often become mesmerized by these differences (Figure 2). The differences are caused by variations in flow-morphology and the effects of high-temperature devitrification (eg. Fink and Manley, 1987; Duffield and Dalrymple, 1990; McPhie et al. 1993).

Flow-facies of silicic lava flows can be grouped into two main classes; coherent and incoherent. Coherent facies consist of the massive, undisrupted interior of a flow. In ideal situations coherent facies consists mostly of a glassy (obsidian) main body that grades outward into a vesicular or pumiceous exterior and inwards into a crystalline core. Within the coherent facies, the spherulitic lithophysal zone, marks the transition between the vitric and crystalline core. Spherulites are radial growths of microcrystalline quartz and feldspar that represent the first stages of high-temperature devitrification of volcanic glass. The crystalline core represents a zone where this process completely replaces the volcanic glass with a fine-grained matrix of microcrystalline quartz and feldspar.

The incoherent facies consists of the rapidly chilled exterior of a flow that disaggregates and breaks apart due to differential motion of the fluid interior. Since this part of the lava flow is broken or brecciated by the flow itself, it is commonly referred to as autobreccia. Basal autobreccia consists of material that crumbles off the front or sides and is buried by an advancing flow (Figure 3). A carapace breccia is the material that forms on the top of an active flow. Clasts in autobreccia are dominated by the pumiceous, vesicular and vitric matrix textures that are found around the edges of the coherent facies core, but in rare instances spherulitic and even crystalline core textures can be found in autobreccia.

Autobreccia rarely contains exotic rock fragments, and this is one of the best ways to distinguish autobreccia from massive outcrops of pyroclastic rock. However, owing to the inherent schizophrenic nature of silicic lava flows, clasts in autobreccia may appear heterolithic to the casual observer.

Not all lava flows display all of the flow-facies variations illustrated in Figure 2. In general, higher viscosity (rhyolitic) flows display more inchorent facies than less viscous flows such as basalt and andesite. Incoherent facies also may dominate around the edges of flows or be more prevalent in slow-moving flows. The absence of carapace breccia may indicate a period of erosion that has removed the top of a flow. In rapidly emplaced sequences, a basal autobreccia may directly overlie the carapace breccia of an older flow.

Another important aspect of silicic lava flows is the tendency for the glassy or vitric matrix to devitrify in the presence of water at relatively low (below boiling) temperatures. Devitrification from hydration produces a light-colored, clay-rich, chalky-appearing matrix. Since lavas tend to flow towards depressions, they commonly encounter water or water-saturated sediment. For this reason, silicic autobreccia is commonly strongly hydrated and often intruded by veins and pockets of opaline quartz. In some lava fields, nearly all vitric material is altered in this way, and the tendency for hydrated lava to look like nonwelded tuff is a serious problem. In many silicic lava fields, as much as 50% of the rock that had been mapped as nonwelded tuff is actually devitrified lava.

Flow-facies variations are relatively easy to recognize and map separately as long as the

exposure is good. However, a map that accurately portrays all of the variations in each flow is extremely time-consuming to produce, and these variations are meaningless unless they are viewed in context of the individual flows. An individual flow typically contains 4 distinct flow-facies consisting of a crystalline core, and a tripartite zonation that extends above and below of spherulitic and vitric coherent facies that grades outward into incoherent facies autobreccia. If you were to map all these boundaries, each flow would have 6 internal contacts, and if you map these all out, before long, your map would be nothing but flow-facies contacts!

Distinguishing lavas from each other

The best way to map silicic lava fields is to use phenocryst mineralogy to identify individual flows and use this criteria to define the contacts between the flows. As mentioned previously, lava flows represent such small volumes of magma that it is highly unlikely for them to preserve any compositional zoning from the parent magma chamber. Use the relative abundances and size/shape ranges of the main phenocryst phases to identify discrete lava flows. Once your eye calibrates to what you should be looking for it becomes relatively easy to identify different flows. Usually, recognition of only a few different phenocryst phases is necessary. The principle phases are quartz, feldspar (plagioclase and sanidine), olivine, hornblende, biotite, and pyroxene.

The biggest challenge for beginning field geologists is to recognize phenocrysts amid the myriad of textural and color variations displayed by the matrix of silicic flows. For example, clear phenocrysts can appear invisible within vitric and hydrated vitric matrix. Mafic phenocrysts stick out easily in light-colored hydrated matrix, but they can be nearly invisible in dark-colored vitric matrix. As a general rule, phenocrysts are easiest to identify when they are suspended in the microcrystalline matrix of the crystalline core facies of a flow. Therefore, it is highly recommended that the field geologist find exposures of the crystalline core facies of a lava before characterizing a flow's phenocryst mineralogy. In many instances the relatively simple first order recognition of abundant versus sparse mafic minerals in light-colored hydrated matrix can often be used to differentiate lavas.

Sanidine and plagioclase can be difficult to distinguish from each other easily and consistently enough to be of much use in defining a phenocryst assemblage. Likewise, biotite, amphibole, and pyroxene, although generally easier to distinguish can also be tricky. In most cases, characterizing a lava's mineralogy based on the presence or absence, and relative abundances of only three minerals or mineral groups should be good enough for first order recognition. The three minerals or mineral groups are: 1) quartz, 2) feldspar, and 3) mafics (hornblende, biotite, pyroxene).

Distinguishing lava from tuff

Silicic lava fields typically include abundant pyroclastic deposits interbedded between the various lava flows. A large proportion of the average silicic lava flow is strongly brecciated and because the breccias are very susceptible to hydration devitrification, they frequently closely resemble nonwelded tuff. However, there are two principal features of nonwelded pyroclastic rock that can be used to distinguish it from hydrated silicic lava: 1) exotic lithic fragments are usually in great abundance in tuffs, and virtually absent in lava autobreccia, and 2) nonwelded

tuff is usually prominently bedded. Experience tells us that in silicic lava fields massive outcrops of light-colored volcanic rock is almost always hydrated devitrified lava breccia. Conversely, if it isn't bedded, it probably isn't tuff. An exception to this rule is that under ideal conditions, basal autobreccia can preserve faint foreset bedding (Figure 3).

Hydrated silicic lava autobreccia is always clast-supported with very poorly-sorted, and very angular clasts. Lithic-rich ash-flow tuff is almost always matrix-supported. Clast-supported textures in pyroclastic rocks are generally restricted to surges, which are easy to identify because they are typically cross-stratified, and ash-fall tuff, which is easy to identify because fall-out deposits are fairly well-sorted. Figure 4 is a flow-chart that should help filter out the differences between lava and tuff

An important component of many lava domes and flow sequences is the block and ash-flow, a monolithic, clast-supported, pyroclastic deposit. Block and ash-flows are formed during the violent collapse of lava domes or when the thick rind or carapace of a lava flow is abruptly punctured (for example as a flow pours over a cliff). Because they are clast-supported and monolithic, block and ash-flows can easily be confused with lava autobreccia. This problem can be overcome by simply lumping the two rock types together. Equating a block and ash-flow with the lava it came from is particularly useful for two reasons. First, because of their clast-supported, poorly-sorted texture, and monolithic character, block and ash-flows more closely resemble lava autobreccia than nonwelded tuff, and by applying the phenocryst mineralogy test to the clasts it should be possible to identify which lava flow or dome the block and ash-flow came from. Secondly, block and ash-flows tend to have higher aspect ratios (thin and widespread versus thick and stubby) than lava flows making them more widely distributed, and this can be very useful for correlation over larger areas. For these reasons, I believe that the block and ash-flow should be considered as another flow-facies variant of the silicic lava flow.

Distinguishing pyroclastic rocks from volcaniclastic sedimentary rock

Volcaniclastic sedimentary rocks are ubiquitous features of practically all volcanic fields. Because both rock types are commonly prominently bedded and they both contain abundant pumice, a combination of sedimentological features need to be considered for differentiating the two rock types. These features are; sorting, abundance of sand-sized material, clast- versus matrix-support, and style of stratification. Sedimentary rocks tend to have more rounded grains (but not always) and many tuffs contain water-worked lithic fragments.

A proper treatment of the classification of volcaniclastic sedimentary and pyroclastic rocks is beyond the scope of this short course, but the flow-chart of Figure 4 should help distinguish these rocks. Many of the breccia units in the Superstition Mountains have been mapped as lahars or laharic breccias (Malone, 1972). Lahars are debris-flows or mud-flows that are formed as a direct result of volcanic eruption, but since there are so many ways for a volcanic edifice to degrade by purely epiclastic processes, it is probably best not to call a deposit a lahar unless somebody has actually seen one form.

FIELD GUIDE

Stop 1 Rhyolite lava flow profile walk-through and remote mapping exercise (4-8 hours): Directions. Take Highway 88 approximately 4.4 miles east from Tortilla Flat. At the very top of the hill turn left (north) onto graded gravel road. Proceed 1.5 miles to locked gate and park. An excellent campsite is present just to the west of here in the flat area at the head of a west-flowing canyon, but access is restricted to 4WD vehicles.

Hike up road through a complex sequence of nonwelded pyroclastic rocks to the first major culvert and drop into the upstream side of the canyon (east side of the road, ~ UTM coordinates 0467300E, 3712950N). Walk up the canyon a few meters to a prominent contact of bedded pyroclastic rocks overlain by volcanic breccia. The breccia is a basal autobreccia that consists of vitric and pumiceous clasts of a 2-5% phenocryst rhyolite lava. The autobreccia is poorly-sorted and clast-supported, but on the upper slopes of the canyon wall to the west, note that faint north-dipping bedding is preserved in this unit. The bedding is interpreted as foreset cross-stratification as illustrated in Figure 3.

Proceed up the canyon to a prominent turn to the left and note on the east wall of the canyon the gradational contact between basal autobreccia overlain by massive vitric lava of the coherent facies interior of this flow (~UTM coordinates: 0467375E, 3712700N). From here as you proceed up the canyon, note the upward increase in abundance of spherulites within the dark vitric matrix of the lava. Eventually, the spherulites increase to a point where they dominate the rock and in some areas, a thin crystalline core zone is present where the matrix is entirely devitrified.

Proceed up the canyon until you reach the contact of the coherent facies overlain by another autobreccia zone that represents the carapace breccia to this flow. Climb out of the canyon to the east through the carapace breccia until you reach the contact between the carapace breccia overlain by bedded pyroclastic rocks. The contact is sharp, but can be quite irregular. Note the change from massive monolithic lava breccia below to thin- to medium-bedded nonwelded tuff with abundant lapilli-sized lithic and pumice fragments. Note also the heterolithic nature of the lithic clasts in the tuff sequence.

Climb up through the bedded pyroclastic sequence and follow this unit to the south and east along the 2800' contour on the map. Head towards the high point of Coronado Mesa, and as you travel, head towards a ledgy outcrop on the north side of a hill mapped as "c" on your map (Figure 5). The ledges are composed of coarse-grained, poorly-sorted, sandy matrix volcaniclastic conglomerate. Clasts in the conglomerate are derived locally, and most come from the rhyolite lava flow that caps Coronado Mesa.

Proceed to the high point of Coronado Mesa (3190'). The entire mesa top is composed of crystalline-matrix, coherent-facies, phenocryst-poor rhyolite lava. From the crest of the mesa you can map a large area of the northeast side of Fish Creek Canyon using a good pair of binoculars. Use two map units: massive lava, and bedded tuff. Take care to spend a good deal of time mapping the contacts between lava and nonwelded tuff across the canyon. Your goal is to fill in the cross-section C-C' (Figure 6) as much as possible. Note that the darker and massive appearing rocks at the bottom of the canyon in the vicinity of the prominent double box is a phenocryst-rich dacitic lava that constitutes the top of the Government Well Formation in this

area. The remaining flows and pyroclastic rocks are part of the Tule Canyon Formation. In choosing contacts between lava and tuff, remember that hydrated devitrified lava breccia, which is commonly present at the top and bottom of flows can appear tuffaceous from a distance. A good rule of thumb is, "if it isn't bedded, it isn't tuff". There are exceptions of course, but this is a good rule to follow. To complete your mapping and cross-section walk along the edge of the mesa to the south and north to gain different perspectives of the canyon view. This exercise should take several hours

There are several good examples of the lenticular snouts or margins of lava flows pinching out at the distal fringe of a flow on the cliff faces across Fish Creek Canyon. At least two such margins are exposed on the prominent cliff to the north (although somewhat concealed by talus cones), and a wonderful exposure of a flow margin is present on a cliff at a bearing of ~035°. Note also that there are a series of north-northwest striking faults that cut across the canyon just upstream from the double box.

Stop 2 Observations of bedded tuff and volcaniclastic rocks (1 hour): Directions. Drive back to Highway 88, and turn left (east) proceeding approximately 3.2 miles to the Fish Creek Hill observation overlook. From here take the short hike out to the promontory.

From the promontory you can see complex faulting and bedding relationships within the same lava and tuff sequence that is exposed farther down Fish Creek Canyon. Note an excellent example of foreset bedding in a basal autobreccia directly to the west across the subsidiary canyon. Note also that the tuff and lava sequence that makes up most of the canyon walls throughout the area is unconformably overlain by volcaniclastic conglomerate and pumiceous, pebbly sandstone. The contact is fairly clear once you know what to look for. The bedding in the sedimentary rocks is consistent, and gently dipping to the southwest, whereas the bedding in the tuffs is highly erratic. This is because bedding in the pyroclastic rocks often blankets the irregular upper surface of underlying lava flows.

In an area where the regional dip is nearly horizontal such as along Fish Creek Canyon, most of the dips in the pyroclastic rocks should be very gentle, but locally they can be up to 34° (angle of repose). The map for this area shows that gentle dips in the tuffs dominate, but that dips up to 34° are also present. This is important to remember while mapping bedded tuff in areas where regional dips are fairly steep. For example, if the bedded tuff sequence of Fish Creek Canyon were tilted to 45° (as it is in the First Water Canyon area along Highway 88 southwest of Canyon Lake) then the possible range in dips would be between 11° and 79°. These extremes should not be common or persistent over large areas, but it is an important feature to keep in mind when you try to evaluate atypical dips.

References

American Commission on Stratigraphic Nomenclature, 1970, Code of Stratigraphic Nomenclature, 21 pp.

Duffield, W. A., and Dalrymple, G. B., 1990, The Taylor Creek Rhyolite of New Mexico: a rapidly emplaced field of lava domes and flows: Bulletin Volcanologique, v. 52, p. 475-487.

Ferguson, C. A., and Skotnicki, S. J., 1996, Rapid early Miocene extension (60%) of the northern Kofa Mountains tilt-domain and its relationship to adjacent tilt-domains and core-complexes of southwest Arizona (abs): Geological Society of America Abstracts with Programs, v. 28, no. 7.

Ferguson, C. A., and Trapp, R. A., 2001, Stratigraphic nomenclature of the Miocene Superstition volcanic field, central Arizona: Arizona Geological Survey Open-File Report 01-06, 103 pp.

Fink, J. H., and Manley, C. R., 1987, Origin of pumiceous and glassy textures in rhyolitic flows and domes: Geological Society of America Special Paper 212, p. 77-88.

Gilbert, W. G., and Ferguson, C. A., 1997, Geology of the Horse Mesa Dam quadrangle, Maricopa and Gila Counties, Arizona: Arizona Geological Survey Open-file Report 97-15, 14 pp., 3 sheets, 1:24,000 scale.

Hildreth, W., 1979, The Bishop Tuff: Evidence for the origin of compositional zonation in silicic magma chambers: GSA Special Paper 180, p. 43-75.

Hildreth, W., 1981, Gradients in silicic magma chambers: Implications for lithospheric magmatism: Journal of Geophysical Research, v. 86, p. 10,153-10,192.

Isagholian, Varush, 1983, Geology of a portion of Horse Mesa and Fish Creek Canyon areas, central Arizona: Tempe, Arizona State University, M.S. thesis, 73 p., 1 sheet.

Malone, G.B., 1972, The geology of the volcanic sequence in the Horse Mesa area, Arizona: Tempe, Arizona State University, M.S. thesis, 68 p., 1 sheet, scale 1:24,000.

McIntosh, W. C., and Ferguson, C. A., 1998, Sanidine, single-crystal, laser-fusion 40Ar/39Ar geochronology database for the Superstition volcanic field, central Arizona: Arizona Geological Survey Open-file Report 98-27, 74 pp.

McPhie, J., Doyle, M., and Allen, R., 1993, Volcanic textures; a guide to the interpretation of textures in volcanic rocks: Centre for Ore Deposit and Exploration Studies, University of Tasmania, 198 pp.

Ross and Smith, 1961, Ash-flow tuffs: their origin, geologic relations and identification: USGS Special Professional Paper 366,

Smith, 1960, Zones and zonal variations in welded ash flows: USGS Special Professional Paper 354-F

Smith and Bailey, 1966, The Bandelier Tuff: A study of ash-flow eruption cycles from zoned magma chambers: Bulletin Volcanologique, v. 29, p83-104.

Suneson, N.H., 1976, The geology of the northern portion of the Superstition-Superior volcanic field, Arizona: Tempe, Arizona State University, M.S. thesis, 123 p., 2 sheets, scale 1:48,000.

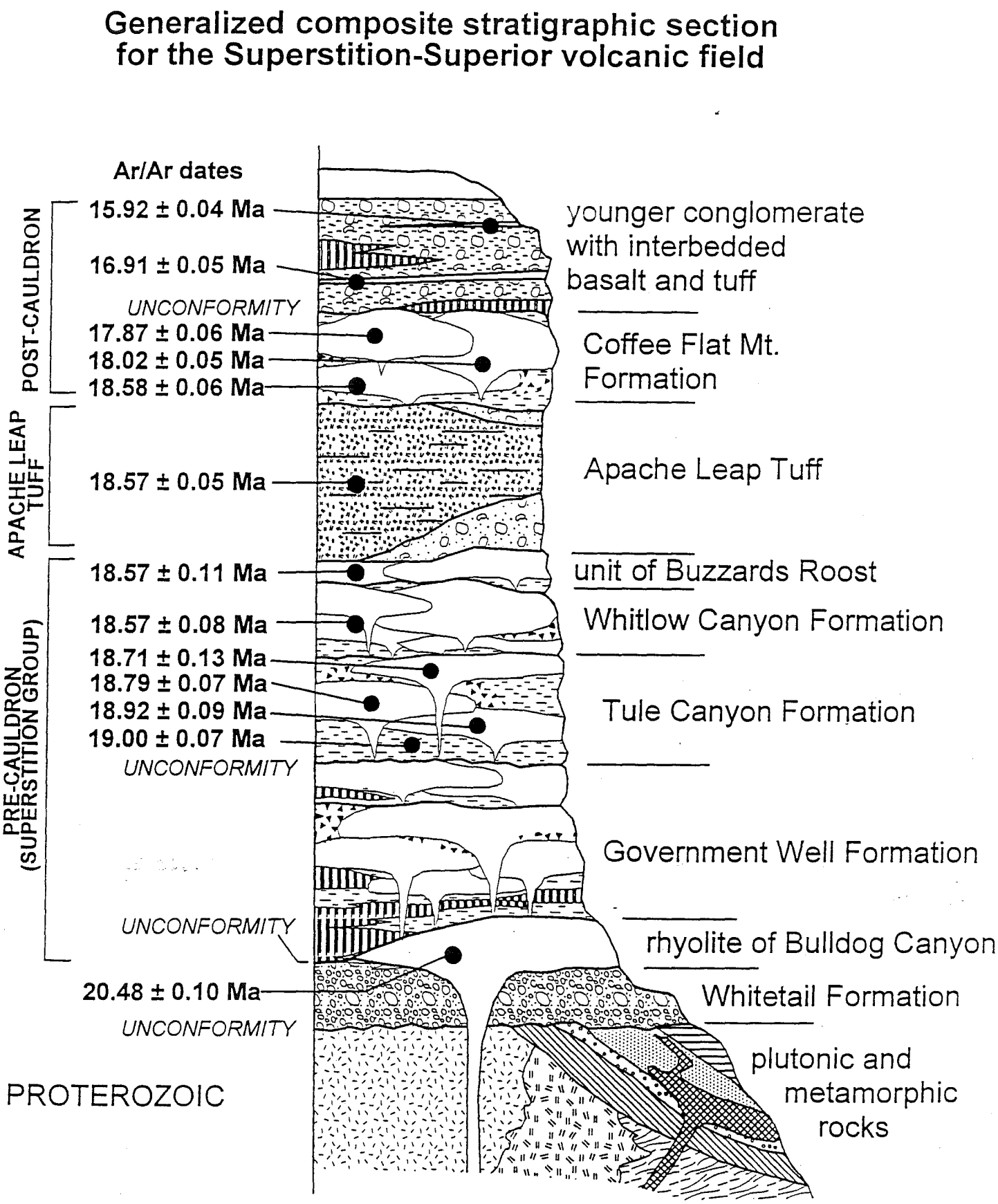


Figure 1 Generalized volcanic stratigraphy and geochronology of the Superstition volcanic field (McIntosh and Ferguson, 1998). The contact between the Government Well and Tule Canyon formations is marked by the prominent color change from dark to light up-section in the lower part of Fish Creek Canyon.

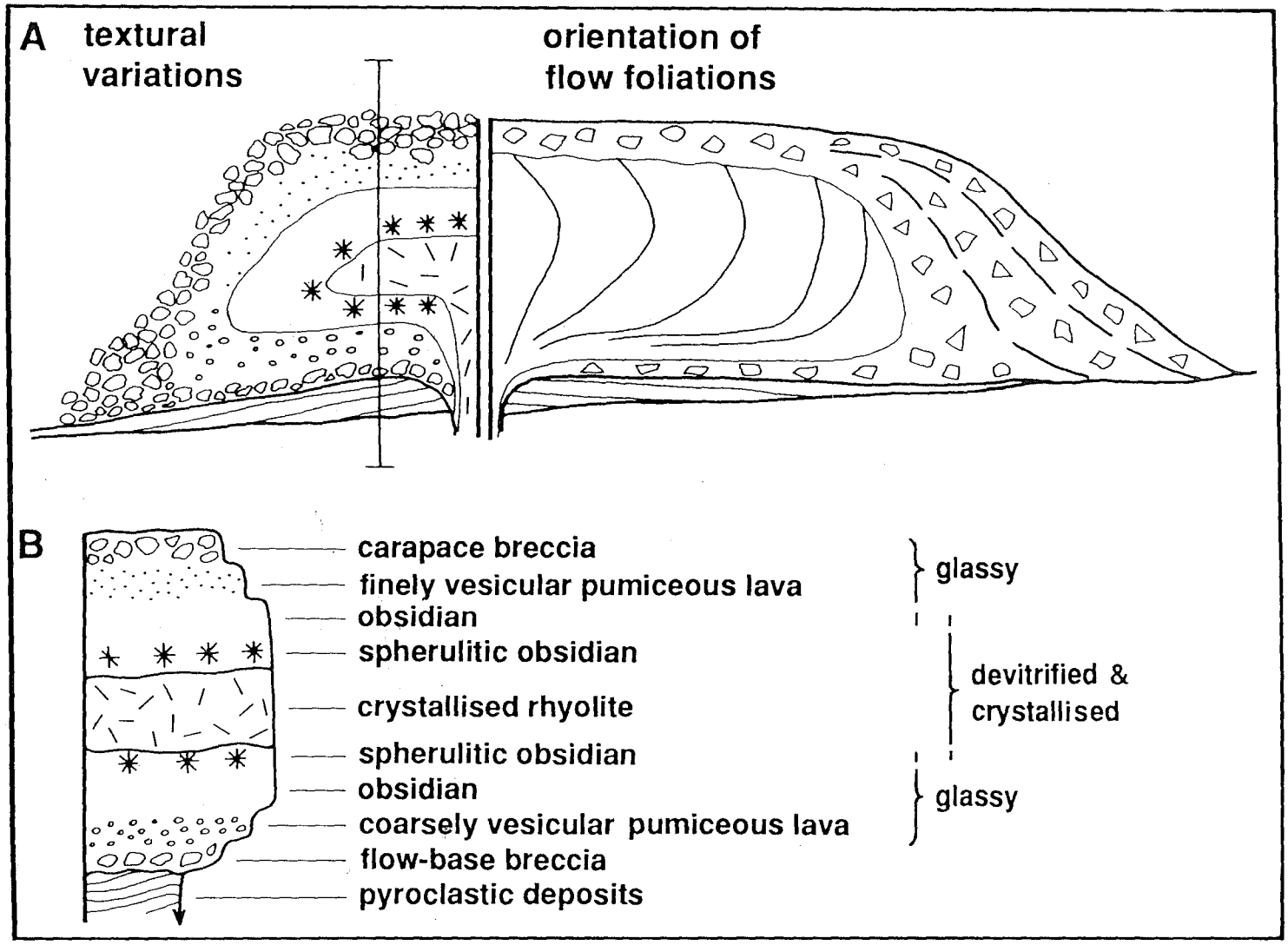


Figure 2 Taken directly from Figure 33 of McPhie et al., 1993. (A) Schematic cross-section through a subaerial silicic lava flow. The left side shows the internal textural variations arising from vesiculation, devitrification, and flow fragmentation. The right side shows the orientations of internal flow foliations, and crude layering in flow margin talus breccia. (B) Vertical section through the flow at the position indicated in (A), showing the major textural zones. Modified from Fink and Manley (1987) and Duffield and Dalrymple (1990).

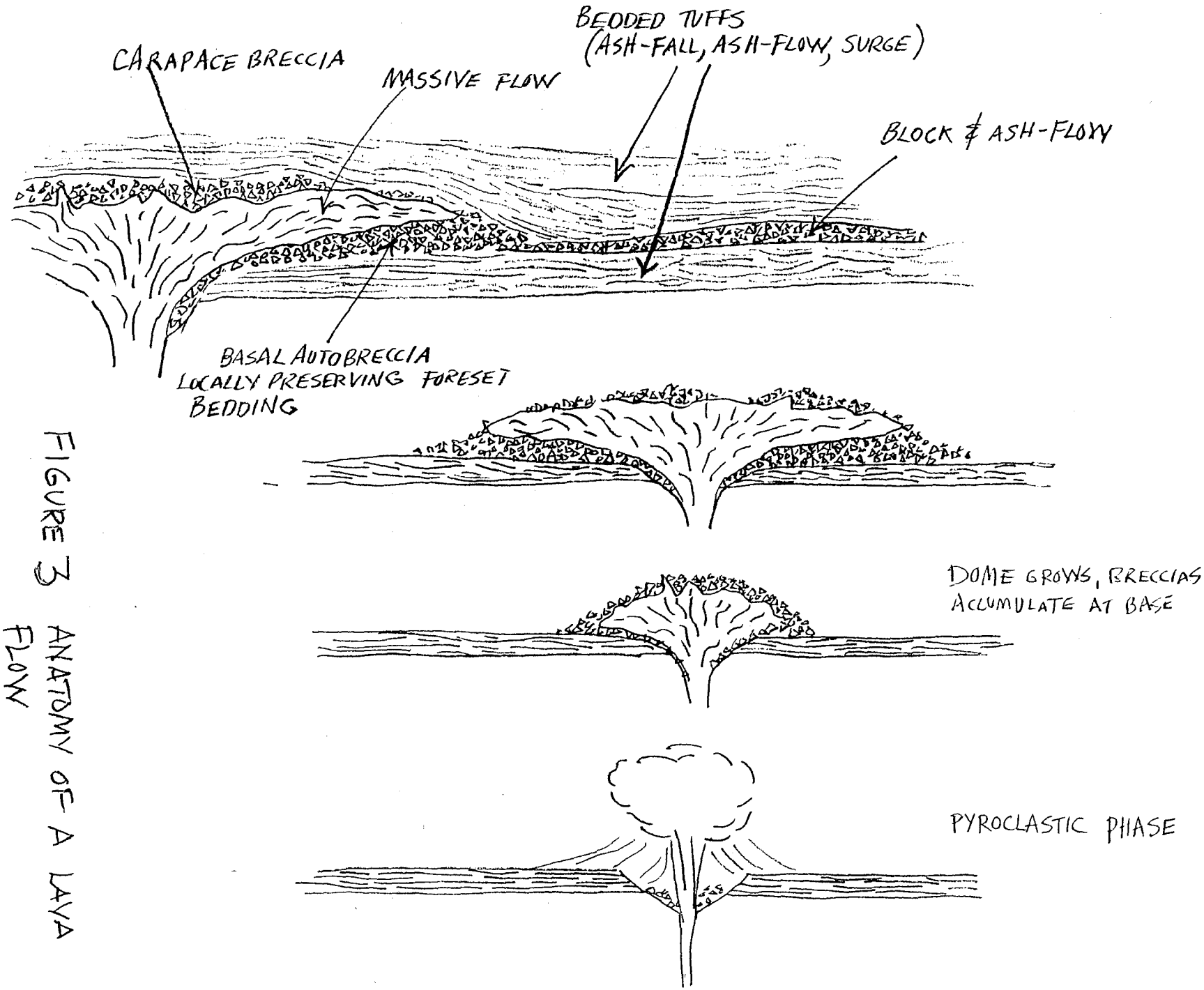
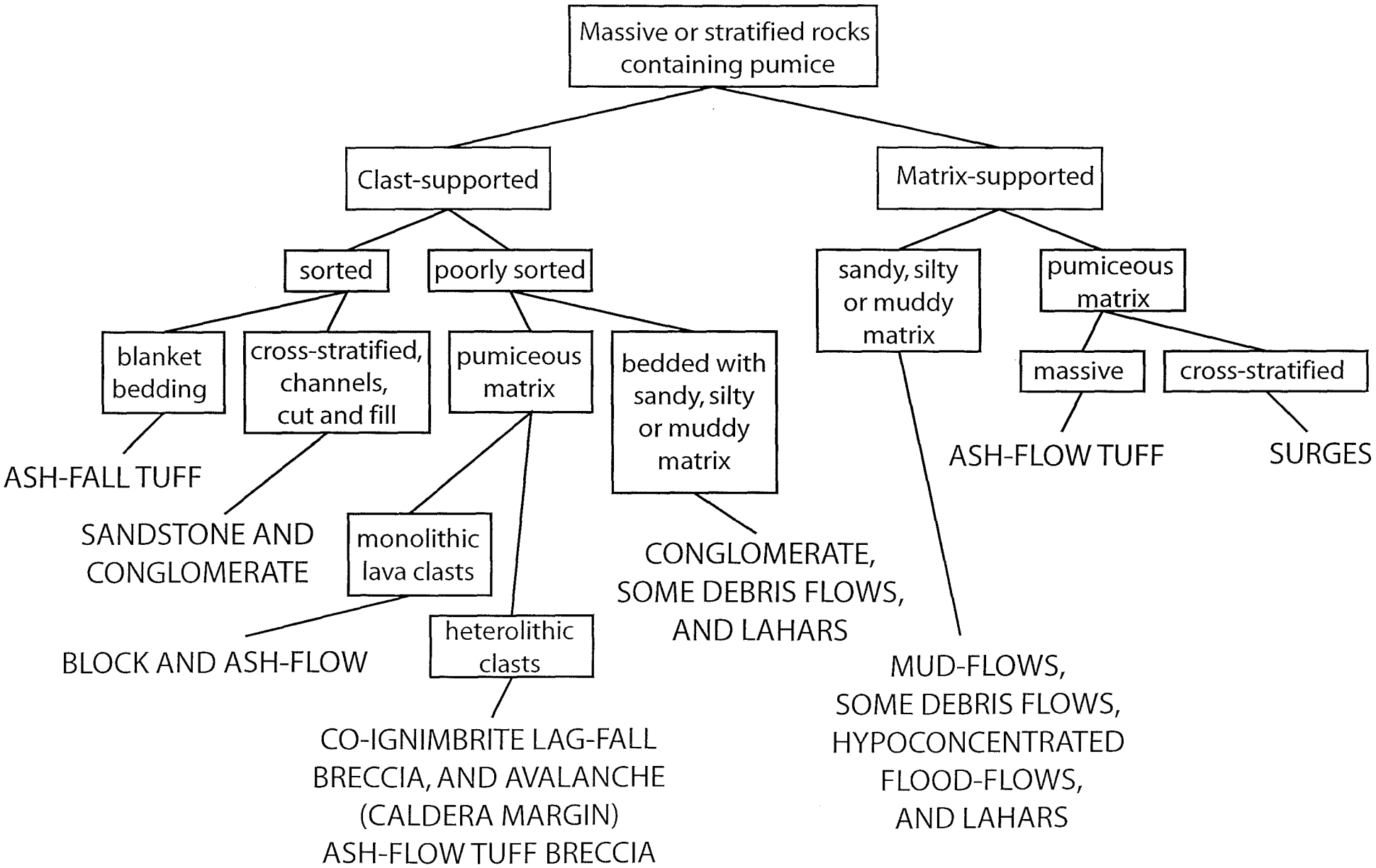
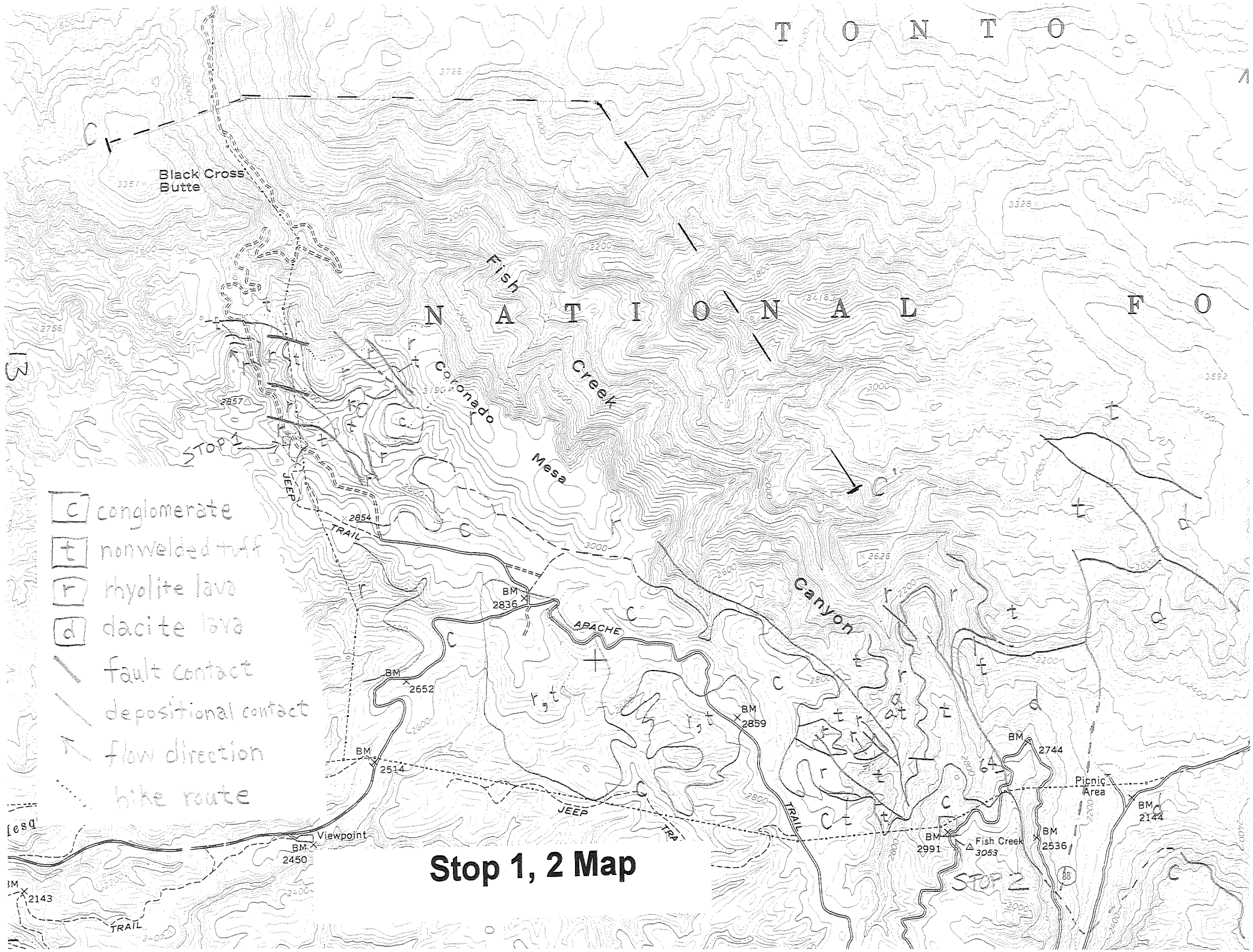


FIGURE 3 ANATOMY OF A LAVA FLOW

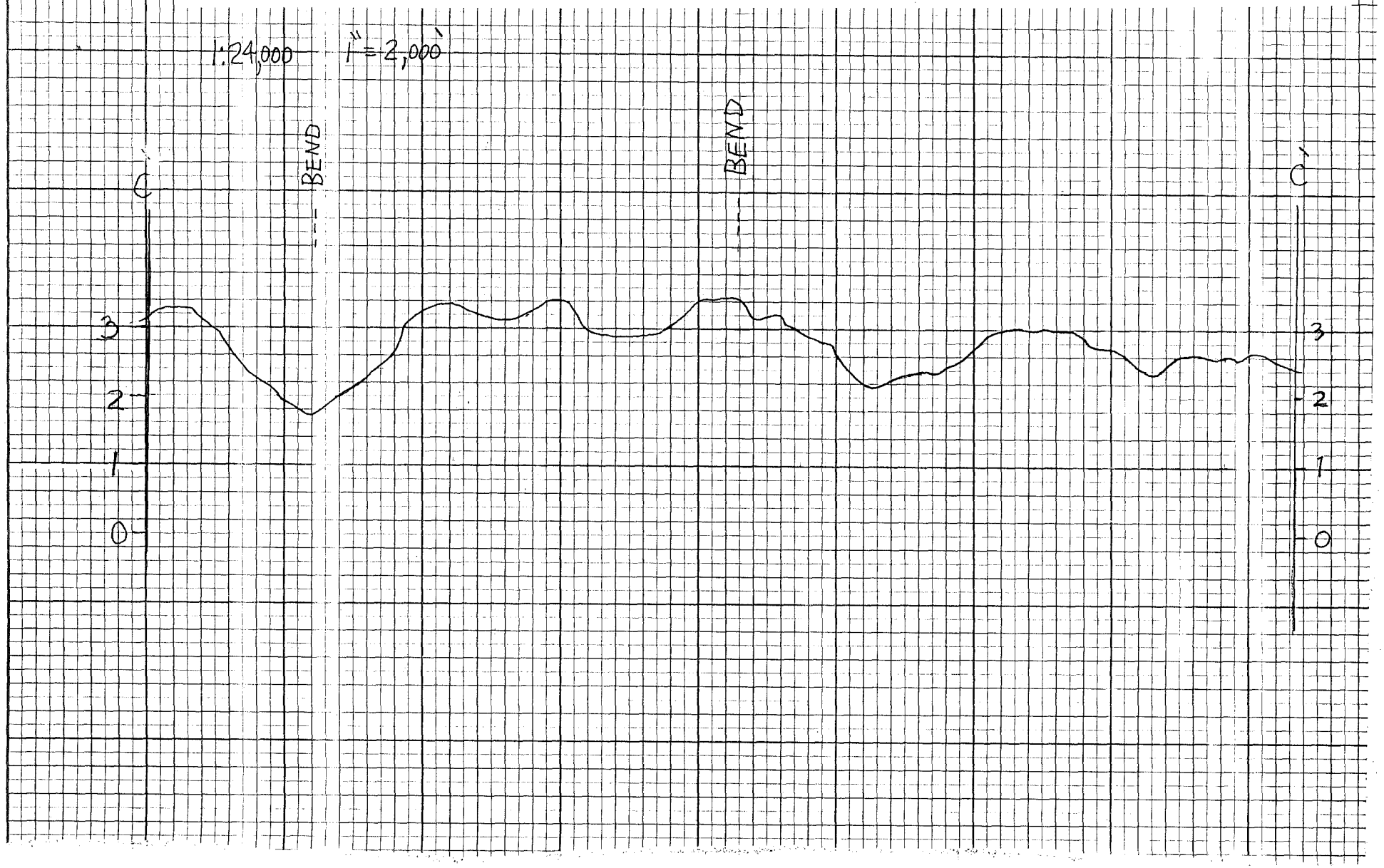
Figure 4. Flow chart for distinguishing tuff from volcaniclastic sedimentary rocks



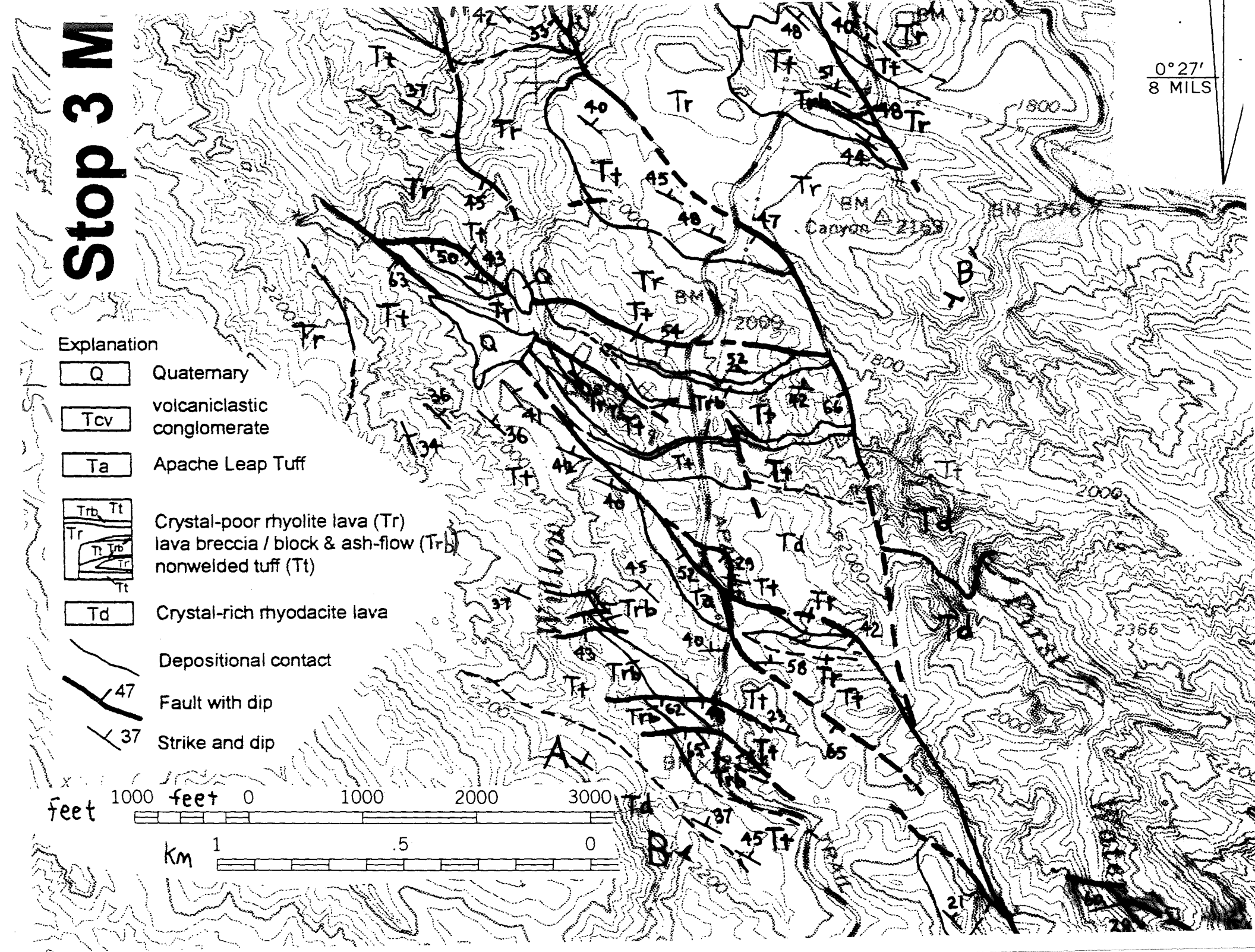

TONTO
NATIONAL FO
Black Cross Butte
Fish Creek
Coronado Mesa
Canyon
STOP 1
STOP 2
JEEP TRAIL
APACHE
JEEP TRAIL
TRAIL
Viewpoint
Picnic Area
Fish Creek
BM 2836
BM 2652
BM 2514
BM 2859
BM 2744
BM 2991
BM 2536
BM 2144
BM 2450
BM 2143
2854
2857
2626
3053
c conglomerate
t nonwelded tuff
r rhyolite lava
d dacite lava
fault contact
depositional contact
flow direction
hike route

Stop 1, 2 Map

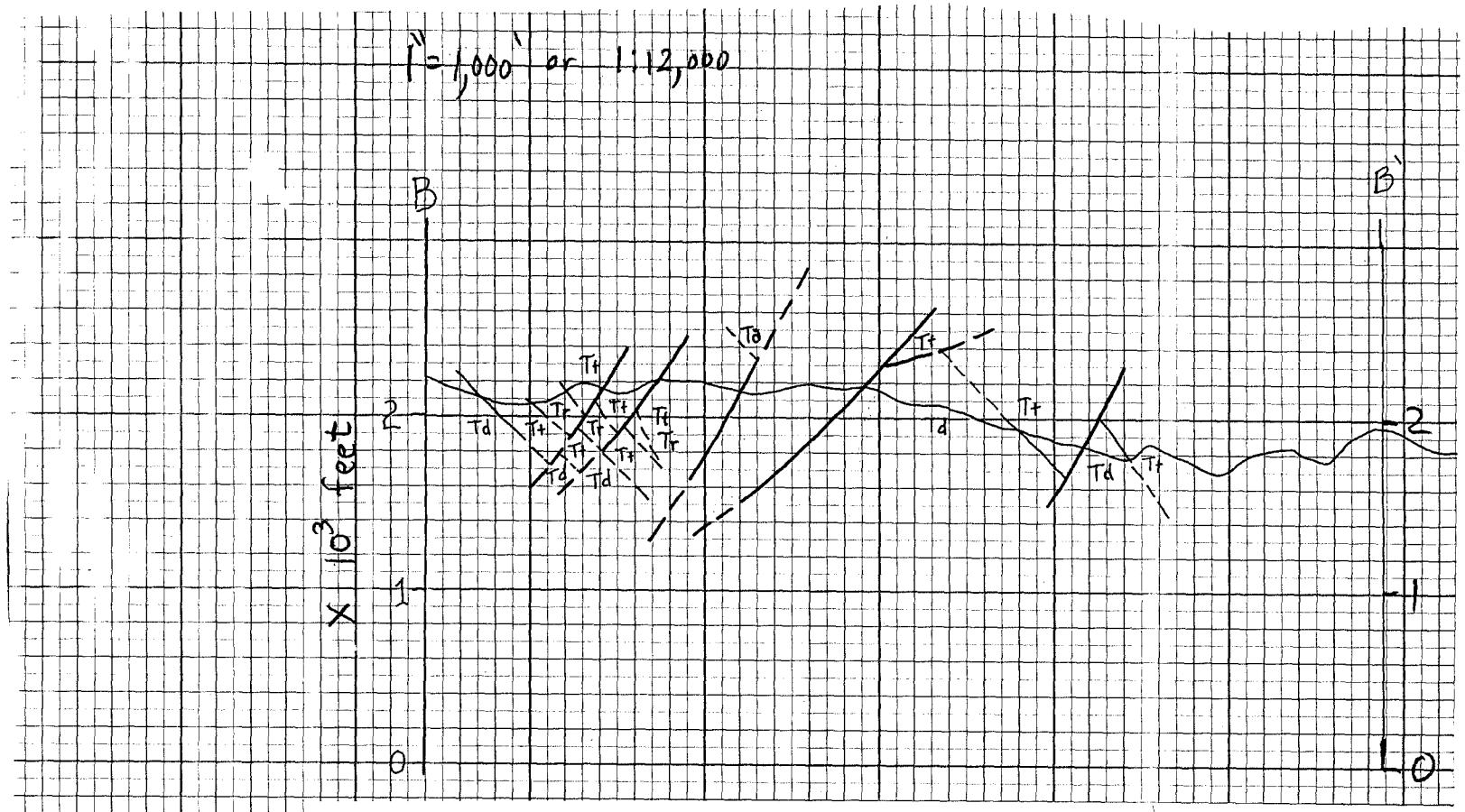
Stop 1 Cross-section



Stop 3 M



0°27′
8 MILS
Explanation
Q Quaternary
Tcv volcaniclastic conglomerate
Ta Apache Leap Tuff
Crystal-poor rhyolite lava (Tr)
lava breccia / block & ash-flow (Trb)
nonwelded tuff (Tt)
Td Crystal-rich rhyodacite lava
Depositional contact
47 Fault with dip
37 Strike and dip
feet 1000 feet 0 1000 2000 3000
Km 1 .5 0
Canyon
BM 1676
BM 1720



Stop 3 Cross-sections