Rolfe Erickson

(Rough Draft)

GIANT INTRUSIVE BRECCIA COMPLEX

DOS CABEZAS MOUNTAINS

ARIZONA

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align

Explanation of Units

PC pi	**Precambrian Pinal Schist undifferentiated**
PC piq	**Precambrian Pinal quartzite**
PC gr	**Precambrian granite**
PC grbr	**Breccia of granite fragments**
PC hc	**Precambrian Happy Camp dacite**
Ps	**Paleozoic sediments undifferentiated**
Ks	**Mesozoic sediments undifferentiated**
Kb	**Cretaceous Bisbee Formation**
Kms	**Muskog Spring ignimbrite**
Kdcp	**Dos Cabezas Peaks ignimbrite**
vb	**volcanic breccia undifferentiated**
gvb	**green breccia**
pvb	**purple breccia**
wvb	**white breccia**
Tm	**Mascot stock**
Tsc	**Silver Camp stock**
Tf	**Tertiary felsite**
QTal	**Quaternary and Tertiary alluvium**

Explanation of Symbols

Clast or layer foliation in breccia

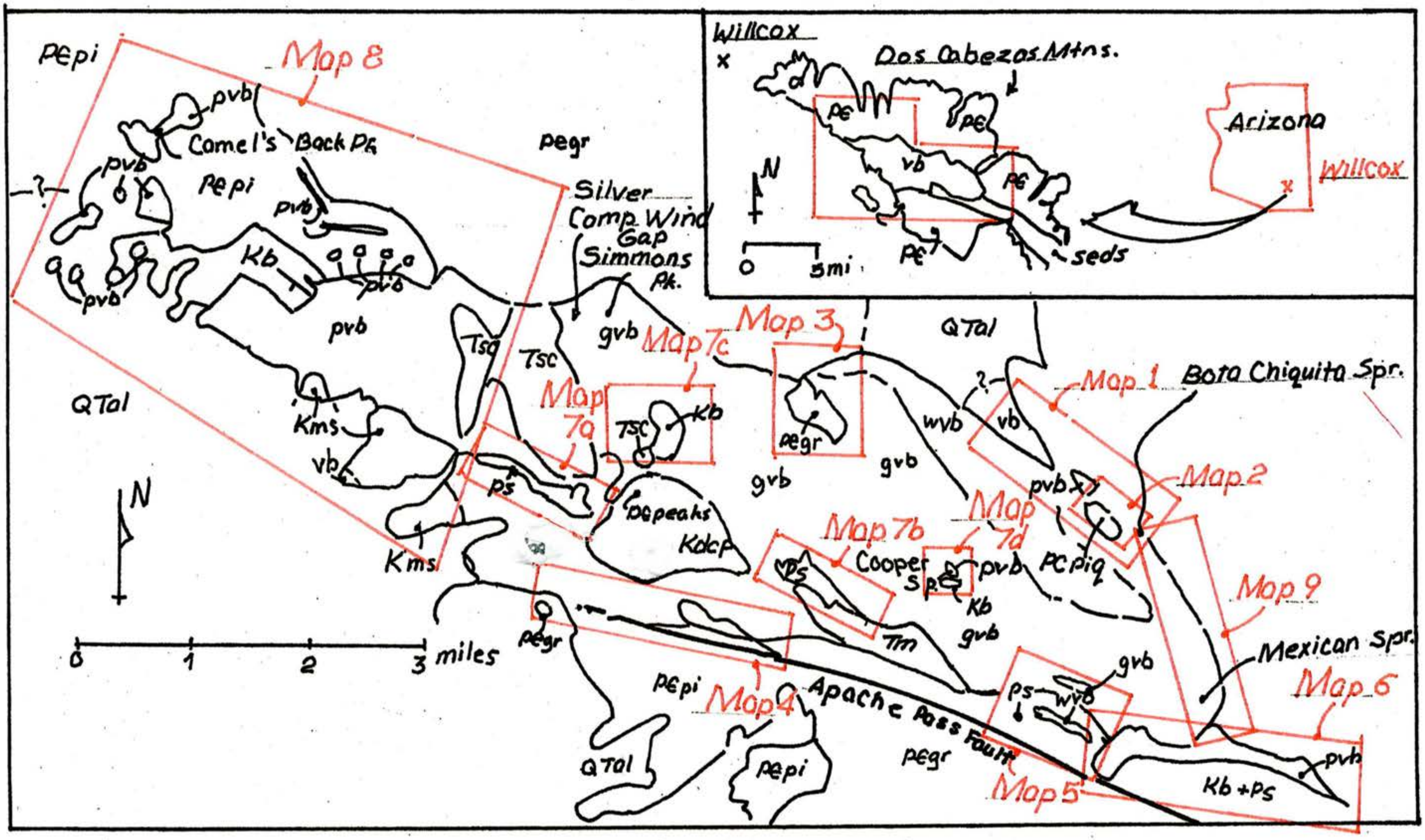
Strike and dip of beds

Strike and dip of fault

Strike and dip of contact

Strike and dip of vesicles

Strike and dip of relict beds in quartzite.



Mapa: Map of the intrusive breccia terrane
Dos Cabezas mountains, Arizona

GIANT INTRUSIVE VOLCANIC BRECCIA COMPLEX IN THE DOS CABEZAS MOUNTAINS, ARIZONA

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Abstract

The Dos Cabezas mountains are a medium-sized range outcropping in southeastern Arizona near the town of Willcox. They are dominately a Precambrian complex composed of 10 granitoid plutons and 3 multi-km^2 terranes of Pinal Schist and Bear Canyon Series. (Erickson, 1969 and 1993). This Precambrian complex is overlain by two deformed Mesozoic ignimbrites, and all these older units are intruded by several Mesozoic plutons and mid-Tertiary dikes. The oldest ignimbrite is 67 Ma; I judge this is the approximate age of the slightly younger breccia system as well. Paleozoic and Mesozoic sedimentary units typical of southeast Arizona are also found (Erickson, 1969). All these units are cut by strands of the regional WNW striking Apache Pass fault system. irregularly shaped

These preexistent units are cut by innumerable intrusive breccia bodies with sizes ranging from small 1-5 m dikes and pods to bodies many kilometers across. These are roughly classified here by matrix color into green, purple, and white groups. The green breccias are by far the most abundant of these.

In their post-Precambrian-development, active faults forming in the Apache Pass tectonic system extended into the center of the Dos Cabezas range, where I hypothesize they outlined blocks of crust up to several kilometers across. These blocks became partly or wholly detached from their walls; and they sank into the fluidized main green breccia body.

The largest green breccia body contains four giant blocks of wall units up to 3 km in maximum dimension, wholly detached from their original location and probably sunk from their original level; these are each partly surrounded by fields of blocks in breccia matrix grading down from multi-kilometer size to hand specimen size and then down to dust. I call such areas block fields. The intrusive contacts of the breccia bodies with their wall units have ~ 1 km of relief, and are commonly well exposed.

The breccia bodies were intruded into their walls and roofs as masses of fluidized fragments transported upwards by gases rising vigorously from deeper-seated magma. The giant blocks in the breccia complex were sinking in the fluidized beds when fluidization ceased, in the same manner as similar giant blocks in kimberlite breccia pipes in Africa (McCallum, 1985).

There are no surficial breccia eruptive units preserved in the breccia complex, but see Shawe and Snyder (1988) and Shawe (1985)

The green breccia alone has been autometamorphosed under hornblende-hornfels facies conditions; abundant metamorphic epidote colors it green.

Presence of a ~ 1 km^2 exposure of typical green breccia in the Circle I Hills (Erickson, 1988), 20 km west of the Dos Cabezas mountains, suggests the breccia terrain may be much more widely distributed than can presently be demonstrated.

INTRODUCTION

very large

This book describes an unusual intrusive breccia complex located in the central Dos Cabezas mountains, just southeast of Willcox in southeastern Arizona.

These mountains are dominantly a ~ 150 km^2 Precambrian complex, composed of three large terranes of older Pinal Schist and Bear Canyon sequence, (Erickson, 1959 and 1993) which are intruded by ten younger Precambrian granitoid plutons and several Mesozoic and Cenozoic ignimbrites, stocks and dikes (Erickson,1981). The major lateral slip Apache Pass fault zone cuts WNW through the southern part of the range; just north of the fault, and parallel to it is a circa 1 km wide strip of south-dipping Paleozoic and Mesozoic sedimentary rocks that lie unconformably on the Precambrian units (Erickson, 1969; Map a)

In the core of this range, elongated parallel to and just north of the Apache Pass fault trace, and intruding all of the above units except the Cenozoic stocks and mid-Tertiary dikes, is an unusual complex of undeformed intrusive lithic volcanic breccias containing dozens of individual units, that underlie a 45 km^2 elongated oval area 17 km long by up to 3 km wide (Map a). (Picture 1)

The walls of the complex locally contain giant breccia dikes up to 3 km long by 200 m wide, which are often well displayed in terrain with a kilometer or more of relief. The main breccia body also includes many xenolithic blocks of older sedimentary, plutonic, and volcanic rocks up to 3 km in maximum dimension, derived from the wall units described below.

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Intrusive Contact Between Precambrian Polecat Granite on Left, Mesozoic Green Breccia on Right. Note Clast Foliation in Breccia. Exposure in Howell Canyon.

Picture 1

One prebreccia ignimbrite unit, the Dos Cabezas Peaks Rhyolite, is probably slightly older than the overall breccia complex, and has a zircon age of 67ma. (Erickson, R., 2015). I accept this as the approximate age of the breccia complex as well.

The complex is surely one of the most unusual igneous complexes in the entire western Cordillera.

The author will model the breccias as having been intruded as fluidized fragmental units following the models of McCallum (1985) and Burnham (1985).

Intrusive breccia bodies more than a kilometer or two in maximum dimension are rare in the literature (but see Sillitoe, (1985) and descriptions below). The intrusive breccia complex in the Dos Cabezas range is considerably larger than any of these and is the largest example known to me at present; to emphasize this I refer to it as a *giant* intrusive breccia complex. To further support the *giant* designation, some of the blocks the Dos Cabezas complex contains are much larger than those in any other described intrusive breccia body known to the author, although some blocks in African kimberlite pipes do approach them in size (i.e., Dawson, 1980, his Figure 9); also see the following discussion.

The geology of this complex in the Dos Cabezas mountains has been discussed earlier by Erickson (1968, 1969, 1986a, 1986b, 1992) and by Drewes (1985), Drewes et al (1986, 1988) and Lipman and Sawyer (1985, 1986). Three standard USGS 15 minute quadrangle maps (Dos Cabezas, Simmons Peak, and Railroad Pass) provide a topographic base for maps of this complex. Other geologic maps covering the complex are provided by Cooper (1960), Erickson and Drewes (1984a, 1984b) and Drewes (1985, 1986).

In this book many previously unpublished detailed maps and photographs are provided which illustrate various aspects of the intrusive nature of the complex's breccia units. The maps have a common explanation given with Map a. Their scale varies from 1:6000 to 1:30000; most are 1:12000. Note that their North attitude varies from map to map.

Field contact relationships between breccia system components and their walls are especially important in this study, so the above maps have an unusual feature; places where the exact contact between two units is well exposed in the field are marked with a red capital C on each map. Some of these map locations are also matched with photographs in the body of this book.

The complex's units need to be defined. The term magmatic will be used for igneous bodies formed by crystallization of a hot coherent continuous silicate liquid, and volcanic since the system is essentially an eruptive igneous one. Wholly aphanitic magmatic units with a certain color will be called (color) aphanites. Dominantly aphanitic magmatic units with a visible phenocryst phase will be called (mineral name) phyric aphanite with a color modifier, as, for example, quartz phyric red aphanite. Rock bodies composed of fragments will be called breccias. [Rock names may be applied to individual breccia clasts, but breccia clast populations are usually so complex their components are not listed.]

The southeastern part of the breccia complex lies within the Dos Cabezas Wilderness, centered on Happy Camp Canyon, accessible from the Apache Pass road going south from Bowie, Arizona to the Indian Bread Rocks picnic area, the gateway to Happy Camp Canyon. Other access is across private ranch properties and permission to enter areas of interest must be sought. Land ownership data can be provided by the Cochise

County Assesor's office in Bisbee and the Bureau of Land Management office in Safford, Arizona.

In addition to the breccias described here from the Dos Cabezas range, an intrusive body of green breccia (see below) identical to that in the Dos Cabezas mountains underlies about 1 km^2 of the southern Circle I Hills (Erickson, 1988), about 20 km west of the breccias in the Dos Cabezas Mountains. The existence of this second body of green breccia at some distance from the bodies in the Dos Cabezas range suggests that the whole breccia system may be much more widespread than presently known. No surface eruptive breccias have been discovered in the complex. Work by Shawe and Snyder (1988) and Shawe (1985) show that they do exist in other areas.

Shawe

UNITS IN THE BRECCIA TERRANE

BLOCKS

Some of the blocks in the Dos Cabezas breccias are the largest yet described in the world. Similar but smaller blocks are found in other intrusive breccia terrains. Examples are described in Sillitoe et al (1985; Williams (1932), Gates (1959) and Morris and Kopf (1967). The formation of such blocks is moded le by McCallum (1985). Larger blocks tend to have large numbers of smaller ones scattered around them, in the breccia matrix, forming a pattern I call a block field. emphasize

Perhaps in the general case, the largest group of such large blocks in an intrusive breccia are those found in the kimberlite pipes of Africa. A typical xenolithic block of this type is described for example, from the Premier diamond mine in South Africa by Dawson (1980, especially his Figure 9). Here a solid block of quartzite some 800 m across and as tall vertically largely blocks the pipe. which has sunk

In many kimberlites such blocks have clearly sunk in the pipe as much as a kilometer below their original stratigraphic position in the kimberlite breccia filling the pipe (McCraken and Alexander, 2000) and may be the only surviving fragments of a particular stratigraphic unit for hundreds of kilometers in all directions. Note that the blocks in the Dos Cabezas breccias can all be traced to one or another nearby wall unit. Note also there are four giant blocks in the Dos Cabezas complex that were free in the breccia as it formed and some are greater than one km in maximum dimension, larger than any other block in a pipe to which the author has found reference.

UNITS IN THE BRECCIA TERRANE

WALL ROCK UNITS SURROUNDING THE BRECCIA COMPLEX

North of the Apache Pass fault quartzite, phyllite, and conglomerate of the Pinal Schist and the Bear Canyon sequence (Erickson, 1969. 1993) are intruded by the Happy Camp dacite stock and the Polecat granite stock, all of Precambrian age (Erickson, 1970). Mapa Northeast from the Apache Pass fault lies a fault-parallel band of brown shale or the Cretaceous Bisbee Group, locally including the Glance Conglomerate member of the Bisbee.

And beyond them

lie Paleozoic sediments, dominantly ~~limestone and sandstone~~. ok South of the Apache Pass Fault lies Precambrian Pinal quartzite. All of these units are intruded by volcanic breccias of the Dos Cabezas breccia system, and several have produced blocks of one size or another. No blocks have formed from preexistent breccias.

THE BRECCIAS

move to next page

Breccias are the main component of the Dos Cabezas complex. For the most part, the three types labelled below lie in geographically separate areas. (Map a). The central zone of the complex, between Silver Camp Canyon and Howard Peak, (Map a) is dominantly underlain by green breccia and blocks within it, and composes about 80% of the terrain (Picture 2); the western part of the complex going west from Silver Camp Canyon to Camel's Back peak. (Map a) is underlain dominantly by purple breccia and the blocks it holds, (Picture 3) about 15% of the terrane, and the eastern part of the complex (Map a) from Howard Peak to Tar Box Canyon is underlain by white breccia, about 5% (Picture 4). ~~I will discuss these three units and their characteristics next.~~ All three breccias have intrusive contacts, of the type shown in Picture 1.

THE GREEN BRECCIA, ITS WALLS AND DIKES

The intrusive character of the green breccia is most clearly seen in its contacts with its walls, which have overall a kilometer of relief and many excellent exposures of rock units and their contacts. The following maps illustrate especially informative parts of the circa 30 km of exposed contact of this body. The maps also describe the giant blocks in the breccias.

Most of the central zone of the breccia complex, an area of about 10 km^2, is underlain by green breccia and its contained blocks and block fields (Map a). In the general case this unit is an isotropic lithic breccia dominantly composed of a seriate assemblage of rock fragments of great petrographic variety. The assemblage has a definite upper size limit in a given exposure, typically 1-5 cm but occasionally up to 1-2 dm and rarely to > 1m. The fragments are typically equant and range from sharply angular to perfectly spherical in shape. Fragments continue down to the finest resolvable microscopic sizes. These finest sizes are equant aphanitic

Picture 2
Green Breccia

Lens cap for scale

Picture 3

typical purple breccia
lens cap for scale

Picture 4 typical white breccia
clipboard for scale

grains of many colors, tightly fitted together. Devitrified glass is present in a few local subunits.

The green breccia clast assemblage is complex. Most of the fragments are of a great variety of igneous aphanites and phyric aphanites of many colors and textures; they are oligoclase phyric aphanites where relict plagioclase composition can be determined. The remaining clasts, commonly several % in most samples, are fragments of coarse-grained granite, schist, phyllite, quartzite, sandstone, and limestone. The green breccia often varies rapidly in color, texture, and clast assemblage from outcrop to outcrop, and it may be difficult to define the boundaries of some units. All its features become more variable toward its margins, where it interacts with wall rocks and where its clast assemblage may contain a large percentage of wall rock fragments. At its wall contacts it may only contain wall fragments. No kimberlite fragments or other high pressure units have been observed in the breccias. see intro!

A free crystal component typically makes up several percent of the finer clast sizes. Most of these crystals and crystal fragments are plagioclase in the oligoclase to andesine compositional range where composition can be determined. It is common for some beta-quartz crystals showing resorbtion embayments to be present as well. The rocks in the breccias are not quartz-bearing, so these beta-quartz crystals must have a ~~deep~~ distant source.

In the general case, the fragments in the green breccia are commonly equant and angular. They are also commonly rounded to one degree or another, and the rounding may sometimes approach a perfect spherical form. This latter shape develops in fluidized beds from mutual impact of clasts on one another.

No bedding exists in the breccia matrix and the outcrops have no stratigraphy. The breccia is usually profoundly structurally isotropic.

However, parallel platy fragments are sometimes (<5%) present in local layers, and define a mappable **<u>layer foliation</u>**. (Picture 5) It looks like normal sedimentary bedding but only extends a few m before fading away. Also, some zones have an assemblage of planar clasts which lie parallel to each other, defining a **clast foliation**. (Picture 6) These foliations are caused by individual planer grains or clasts orienting in the fluidized bed. These foliations are plotted on the maps provided here with the customary strike and dip symbol. These foliations are always discontinuous and cannot be followed in the field more than a few meters.

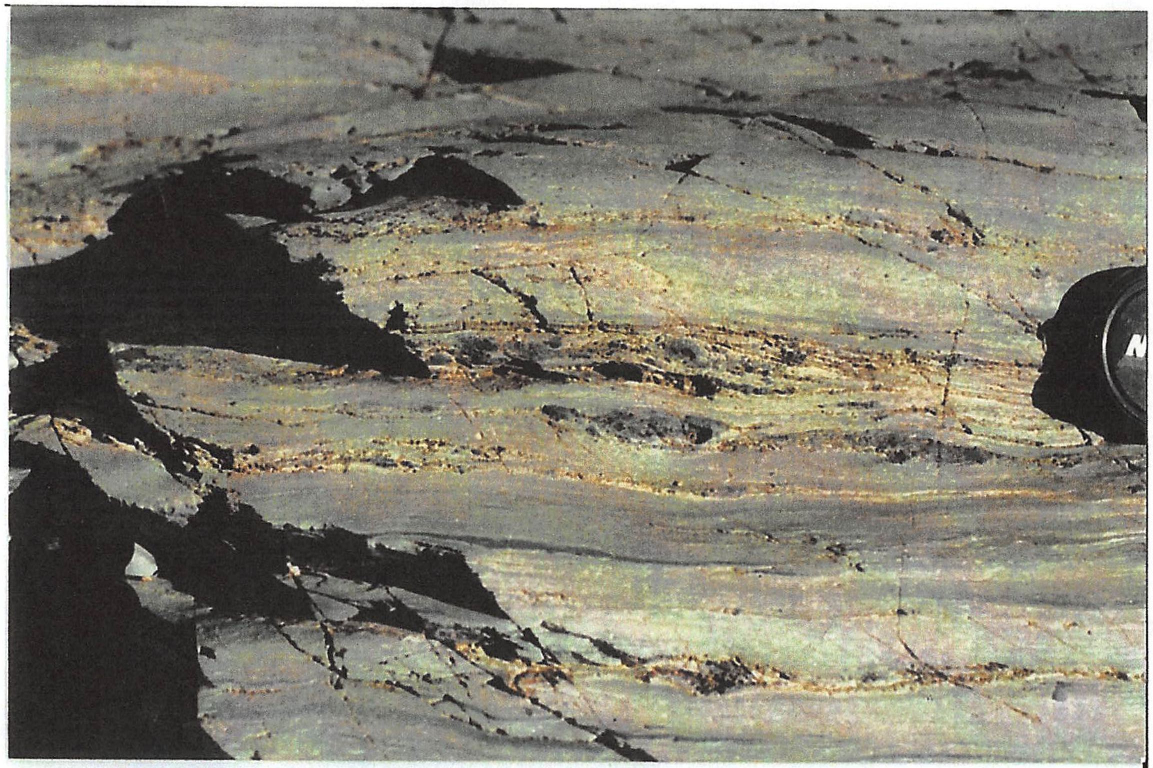
Purple and white breccias also show these foliations at times.

POST GREEN BRECCIA MAGMATIC INTRUSIVES

The green breccias have been intruded by innumerable small magmatic dikes and plugs of green and purple aphanite and phyric aphanite types.

GREEN BRECCIA METAMORPHISM

The mass of fragments in any exposure has undergone considerable autometamorphism marked by the development of sericite and epidote. The epidote typically crosscuts fragment boundaries and is so abundant that it colors the outcrops green; hence the label green breccia. Texturally the epidote varies from aphanitic aggregates to clear crystals up to a cm long.



Picture 5

Layer foliation in green breccia
Lens cap for scale.

Picture 5

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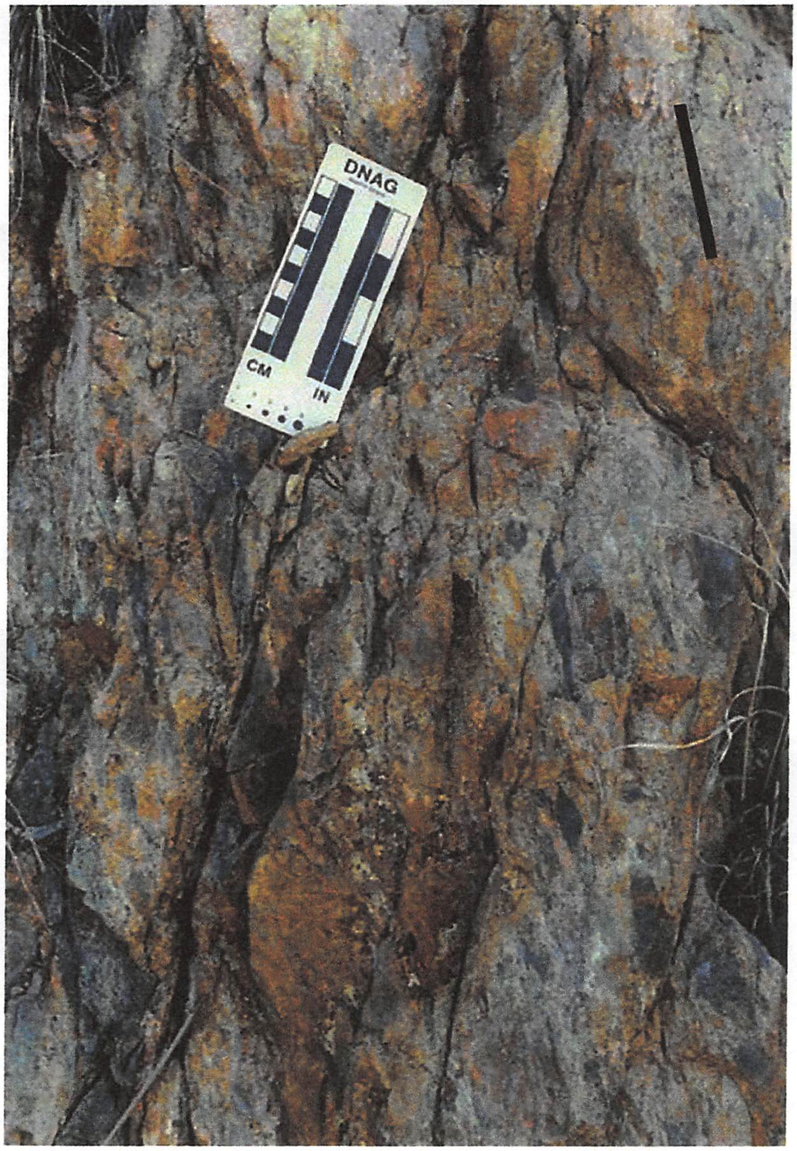


Clast Foliation in white breccia dike cutting Bisbee Group shale. Foliation parallel to black line in upper right.

~~[illegible]~~ 6
Picture

Picture 6

The coarseness of crystallization suggests the recrystallization should be called autometamorphism rather than deuteric alteration. The mineralogy indicates recrystallization temperatures equivalent to those of the albite-epidote-hornfels facies of contact metamorphism, between 350-500 deg. C. The metamorphism is clearly confined to the green breccia outcrops and the clasts it contains, and is modelled by the author as due to the recrystallization of a hot mass of fragments after material emplacement. The autometamorphism has very strongly lithified the green breccia so that it outcrops boldly, both in local outcrops and in the main ridge of the Dos Cabezas range, which is largely composed of green breccia, and which rises 300m above the surrounding country, which is underlain largely by Precambrian units.

GIANT DIKES OF THE GREEN BRECCIA

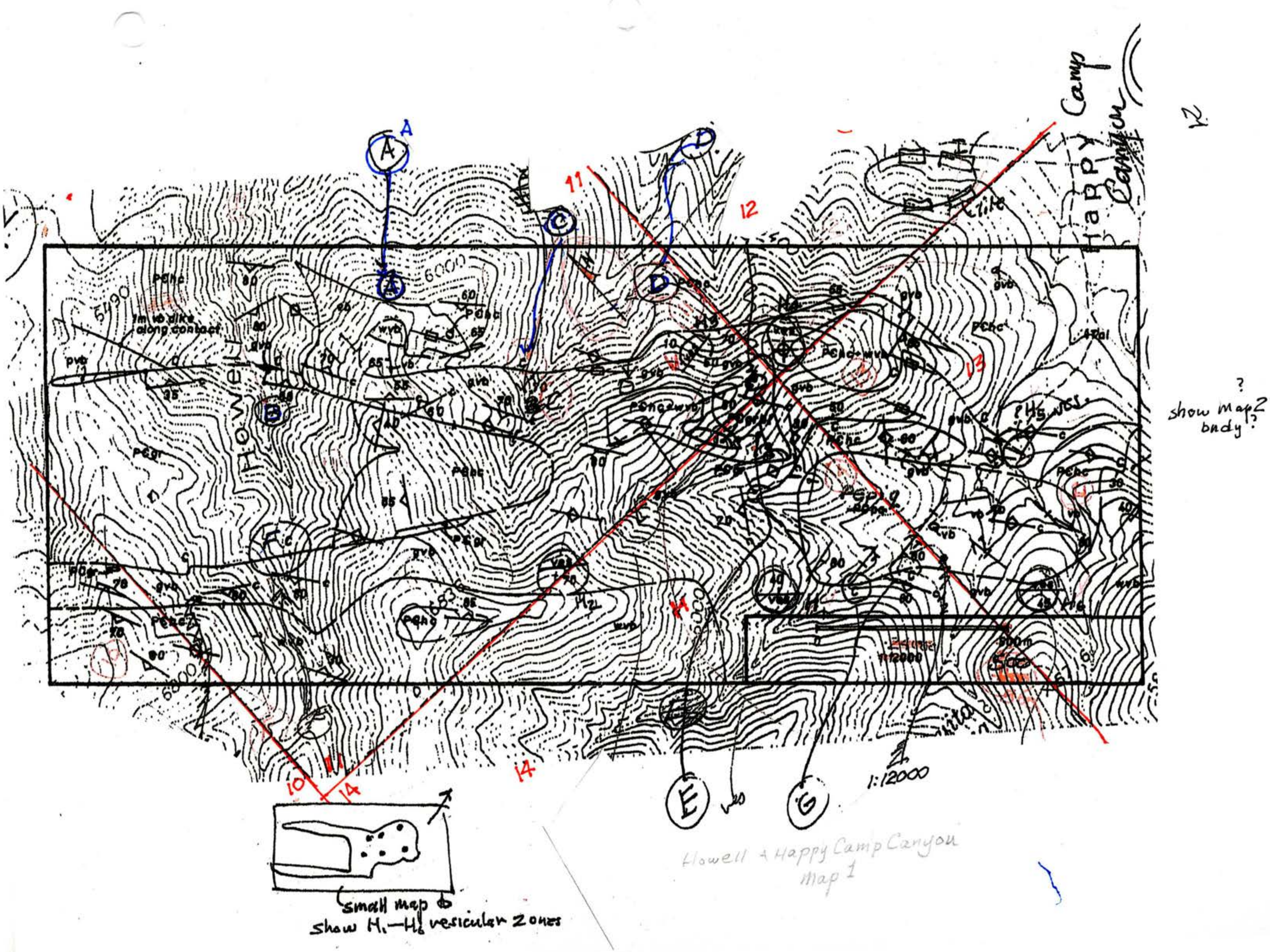
The oldest wall rock unit along the northeastern contact of the main breccia complex is strongly bedded and cross-bedded quartzite of the Precambrian Pinal Schist, and the Precambrian Happy Camp dacite intrusive into it. Both of these units are intruded by Precambrian unfoliated coarse-grained Polecat granite. Abundant blocks of all three of these lithologies in all sizes appear in the green breccia, as well as in the walls.

In the area of Howell and Happy Camp canyons (Map a) these units are intruded by two giant green breccia dikes (Map 1) containing zones of exceptionally large blocks $\geq$1m, and exhibiting clear intrusive contacts with their walls. Neither dike shows any internal layering resembling bedding on any scale, aside from local layer foliation. The dikes are several km long and circa 0.5 km wide. These are the largest breccia dikes described in the world to date so far as I am aware.

The dike complex may most easily be described as being composed of roughly parallel northwest striking outer and inner dikes 0.5 km apart, which partially merge toward the southeast (Map 1) and terminate in smaller dikes striking southeast. I will follow this pattern while describing the dike complex.

The outer dike of green breccia at its northwestern end curves back on itself (location A, Map 1) and encloses a long finger of the Happy Camp Canyon white dacite porphyry wall rock which is brecciated at the end to form a typical white lithic breccia. From this looping end a thin green breccia dike buds off (location B, Map 1), crosses Howell Canyon on a northwest trend, and splits into two purple breccia dikes which continue northwest for circa 0.5 km. The exact contact of this dike may be seen, for example, at location C in Map 1, where the green breccia mixes with dacite fragments over a 2 dm interval, and the contact dips from 90° to 70°S over a narrow interval.

The main body of this outer dike of green breccia strikes southeast ~0.7 km from the looping end at locations B and C on Map 1. It is fine-grained to aphanitic at the wall, grading to an extremely coarse core. The core of the dike in this interval contains a linear zone parallel to its strike, approximately 50 m wide and over 0.5 km long, composed of well-rounded oval clasts of Polecat granite and Pinal quartzite typically 1-5 dm in maximum dimension, and displaying strong clast foliation. (Picture 7, Location D, Map 1). I will emphasize that these rounded blocks occur in a green breccia dike cutting a dacite stock, and were not rounded by sedimentary processes in a sedimentary environment. The dike was


Happy Camp
Canyon
Howell
show map 2
bndy?
1:12000
small map
show H_1—H_6 vesicular zones
Howell + Happy Camp Canyon
Map 1

Picture 7

Picture 7

Large lithic clasts in green breccia.
Clasts are Polecat granite and Pinal lithologies.
Lens cap for scale. Howell Canyon

presumably intruded as a fluidized bed in which the blocks were components, rounded by innumerable mutual impacts.

To the southeast this outer dike broadens and incorporates a large complexly shaped block of the Happy Camp dacite porphyry wall rock, which is mostly brecciated.

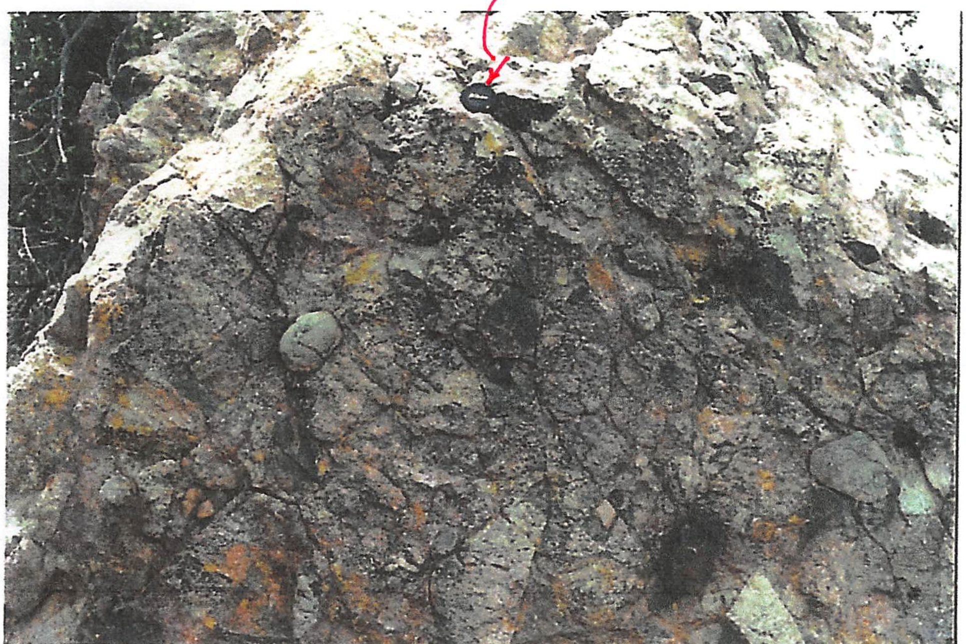
In two places near location E in Map 1 and in NW part of map2 the dacite porphyry is intruded by unique breccia bodies to 50 m across composed largely of well-rounded clasts of Polecat granite (Picture ** 8) and rare quartzite up to several cm in size, contained in a matrix of broken quartz and feldspar fragments from disintegrated Polecat.

This is the best local example of a general phenomenon in this fluidized system – the rounding of clasts. The phenomenon arises from the nature of the fluidized environments – the individual clasts are not held rigidly but move rapidly about an average center, striking each other innumerable times when they do. The clasts are quickly rounded and ground down to finer sizes. The fines so produced become part of the fluidizing agent and finally escape from the top of the fluidized bed.

East of location E on Map 1, this outer dike splits in two and the two smaller dikes strike southeast around a roughly diamond-shaped tongue of the Happy Camp dacite porphyry and finally vanish under talus and alluvium in Happy Camp canyon.

<u>The inner dike</u> of green breccia strikes NW-SE for about 1.3 km around location F in Map 1, crossing 1000 m deep Howell Canyon with steep to vertical contacts which are often visible. It intrudes along the Polecat-Happy Camp contact. As with the outer dike it too contains a long, linear core zone of unusually coarse, usually ovoid clasts, including several Polecat granite clasts over 1 m long, with the whole assemblage exhibiting

cap



Picture 8

Picture 8

Well-Rounded clasts of Polecat granite and Pinal quartzite in green breccia. Lens cap for scale.

strong clast foliation. This dike probably extends five km more to the northwest, to the Elma mine area (Drewes, 1985).

To sum up, both dikes cross canyons 300 m deep with well-exposed contacts and are always intrusive.

THE SOUTHEASTERNMOST ZONE OF THE NORTH CONTACT – DEMONTRATING A NEAR SEPARATION OF A GIANT BLOCK OF PINAL QUARTZITE FROM THE NORTH WALL OF THE BRECCIA COMPLEX

At its southeastern end (Map 1) the inner dike just discussed merges with the outer one. Its southwestern contact swings south and then southeast around a body of cross-bedded Pinal quartzite, 0.7 X 0.3 km in size, (Map 2) that protrudes out 0.3 km into the main breccia mass as a boss from its southern wall. ~~Here the inner green breccia dike merges with the main green breccia body.~~ The contact of the main breccia body swings back northeast around the southern end of the Pinal quartzite body and nearly merges with the outer dike striking southeast toward it. Only ~~in~~ along the southeast contact is the quartzite still in contact with Happy Camp dacite, in its original relationship (location H on Map 2). This very large protruding mass of Pinal quartzite has nearly been cut out of the northeast wall of the breccia complex by intrusion of green breccia dikes ~70 Ma ago along its northern and eastern boundaries; had the intruding dikes been active longer this huge block of quartzite would have been cut completely free, to lie in the green breccia like several other giant blocks in the complex yet to be described (see below). This quartzite ~~block~~ body I call the Happy Camp Canyon quartzite block as that drainage cuts the block.

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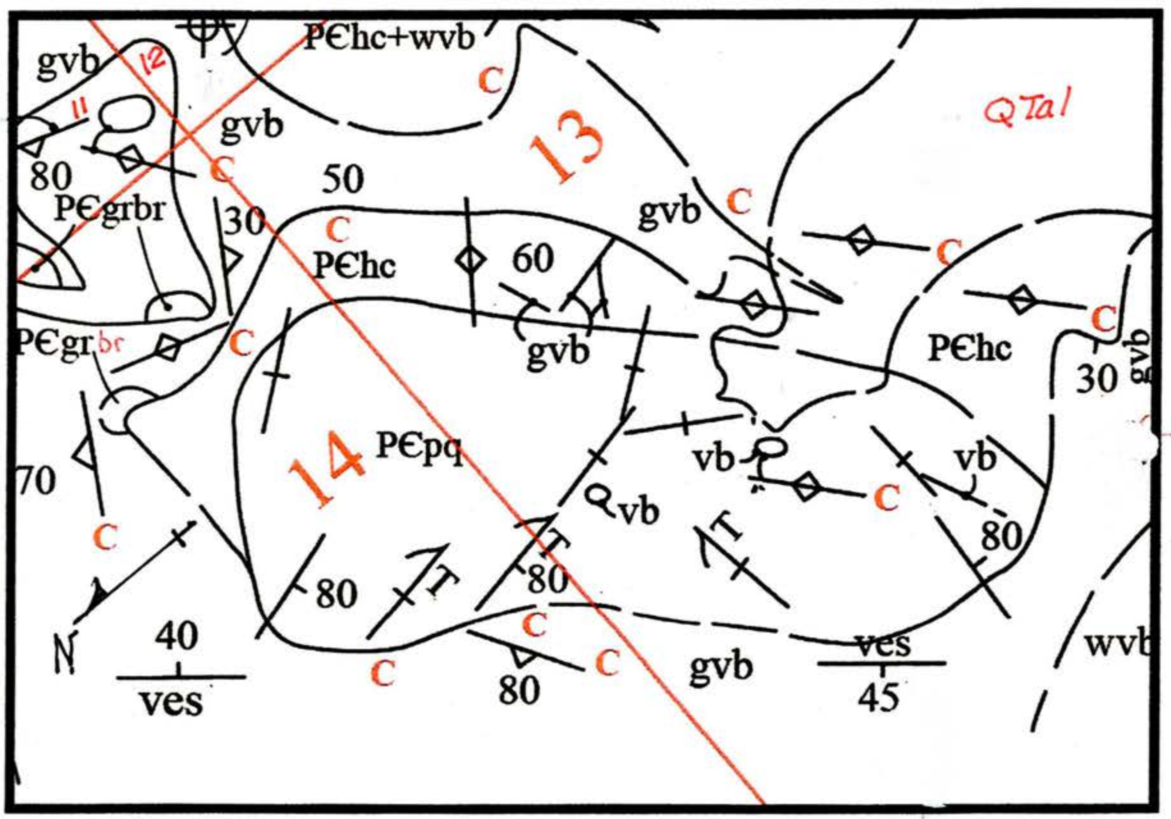

Map 2

bring in contours from Map 1

Happy Camp Canyon Quartzite Block

Map 2

also frontspiece-

Picture 9 shows the exact contact of the inner green breccia dike with this quartzite. This boss of quartzite exhibits a number of intrusive features. The contact dips vertically and all the megascopic fragments in the breccia at the contact are quartzite. Other clast types don't appear until a few meters out into the breccia from the contact. Some of the clasts are planar, and the population exhibits moderate clast foliation parallel to the contact. Just north of this picture location a local planar zone of small clasts to 1 cm exhibits excellent layer foliation near and parallel to the contact. It is clear at this site that the breccia was actively intruding its walls in the same manner as any plutonic body, while orienting and sorting components of different shapes and sizes.

Note on Map 2 several small green breccia dikes cutting the quartzite. similar dikes are found in all the giant blocks and wall units.

VESICLES IN MAP 1

Strike and dip symbols are shown for large planar vesicles marked by the unique label **ves** at six locations (Picture 10, Map 1). These openings sometimes resemble the cavities produced by weathered fiamme in ignimbrites, but they are not. They are commonly filled with a brown carbonate. Thin section study shows they are sharply bounded cavities, often partly filled by drusy euhedral 2-3 mm chlorite crystals lying with (0001) at right angles to the plane of the layer, and/or by brown calcite.

These cavities are interpreted by the author as vesicles formed by gas bubbles in a fluidized bed (Zabrodsky, 1966) and then filled in whole or in part by minerals deposited from solution.

Picture 9

Picture 9
Contact between PE Pinal quartzite block (Happy Camp Cyn block)
and quartzite breccia

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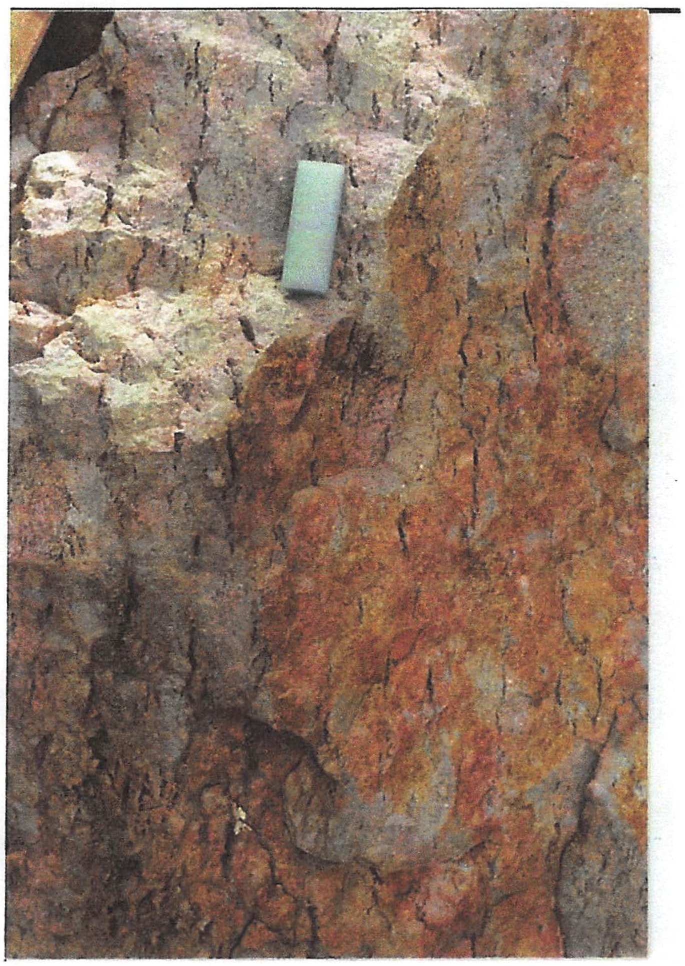


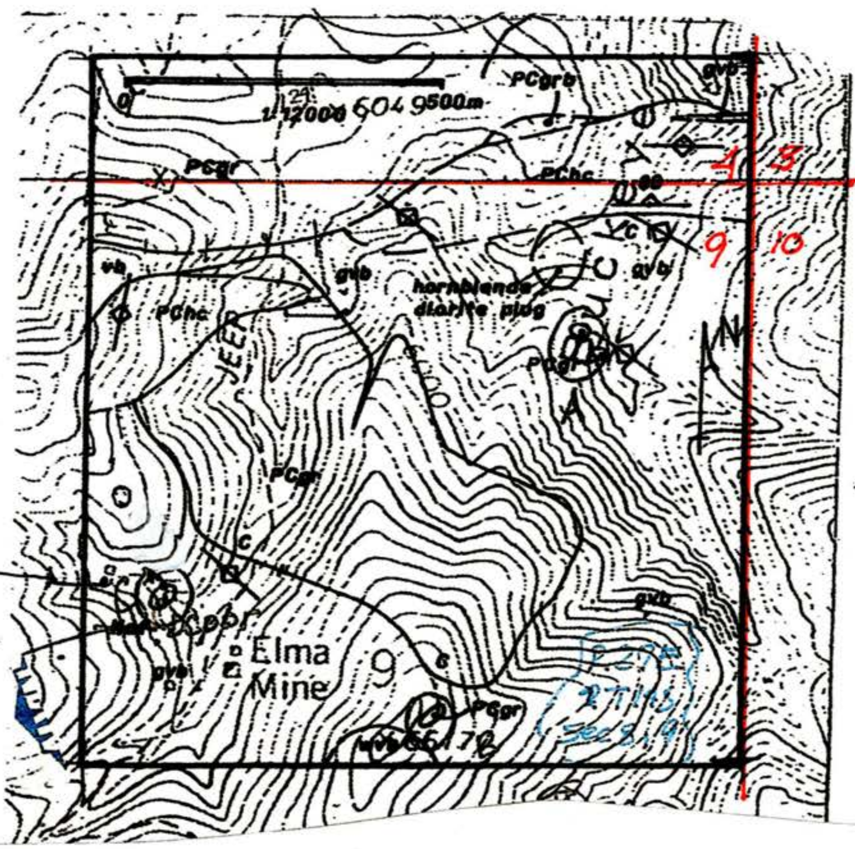
Vesicles in green breccia. Eraser for scale
Picture 10

THE CENTRAL ZONE OF THE NORTH CONTACT – A GIANT BLOCK OF POLECAT GRANITE NORTH OF THE ELMA MINE

In the center of the north contact of the green breccia with Polecat granite, north of the old Elma mine, (Map a, Map 3) a block of Precambrian Polecat granite 0.5 X 0.3 km in size is separated from the main body of the same granite, which makes up the north wall of the complex, by a narrow dike of the green breccia which surrounds the block elsewhere. (See also Drewes, 1985). A dike of the breccia also cuts into the block from the north, and two smaller granite blocks to 50 m lie near the main one, in the green breccia. On an outcrop scale, smaller dikes of the breccia intrude the granite block, and small xenoliths of the granite to hand size lie in the breccia. The intrusive relationships are obvious. I call this block the Elma block (Map 3) after the nearby mine. The intruding green breccia here is mostly structurally isotropic, and shows extreme variation in color and clast size and lithology.

Before separation this granite block had projected out circa 0.5 km into the green breccia mass as a boss from the north wall, very much like the large Pinal quartzite boss described in the previous contact segment. That Pinal body had been nearly cut loose from the north wall by breccia dikes; here that separation is complete. In examining these two blocks we see the operation of the mechanism for producing single giant blocks in subsurface intrusive breccia systems. They are cut out of the walls of the system by fluidized dikes of lithic breccia, advancing along preexistent joints or faults as planes of weakness.

In the vicinity of the Elma mine, exposures of Precambrian granite are frequently brecciated by escaping fluid; an example is shown in Picture 11



Elma Block

Map 3

large block of DC peaks ignimbrite in gvb

Purple breccia intruding Polecat granite
Vicinity of the Elma mine
Picture 11

CENTRAL ZONE OF THE SOUTH CONTACT– BOULDER CANYON TO MALAY CANYON

Next I will examine the southern contact of the main green breccia body against faulted Paleozoic sediments of the Apache Pass fault system. (Map ~~3~~ 4).

The contact here (Map ~~3~~ 4) is complex, the most complex in a complex system. The wall relationships, first, are that a circa 0.5 km wide band of Bisbee shale, Paleozoic limestone, and Precambrian granite, all in fault contact, strike WNW immediately north of the Apache Pass fault -Map a

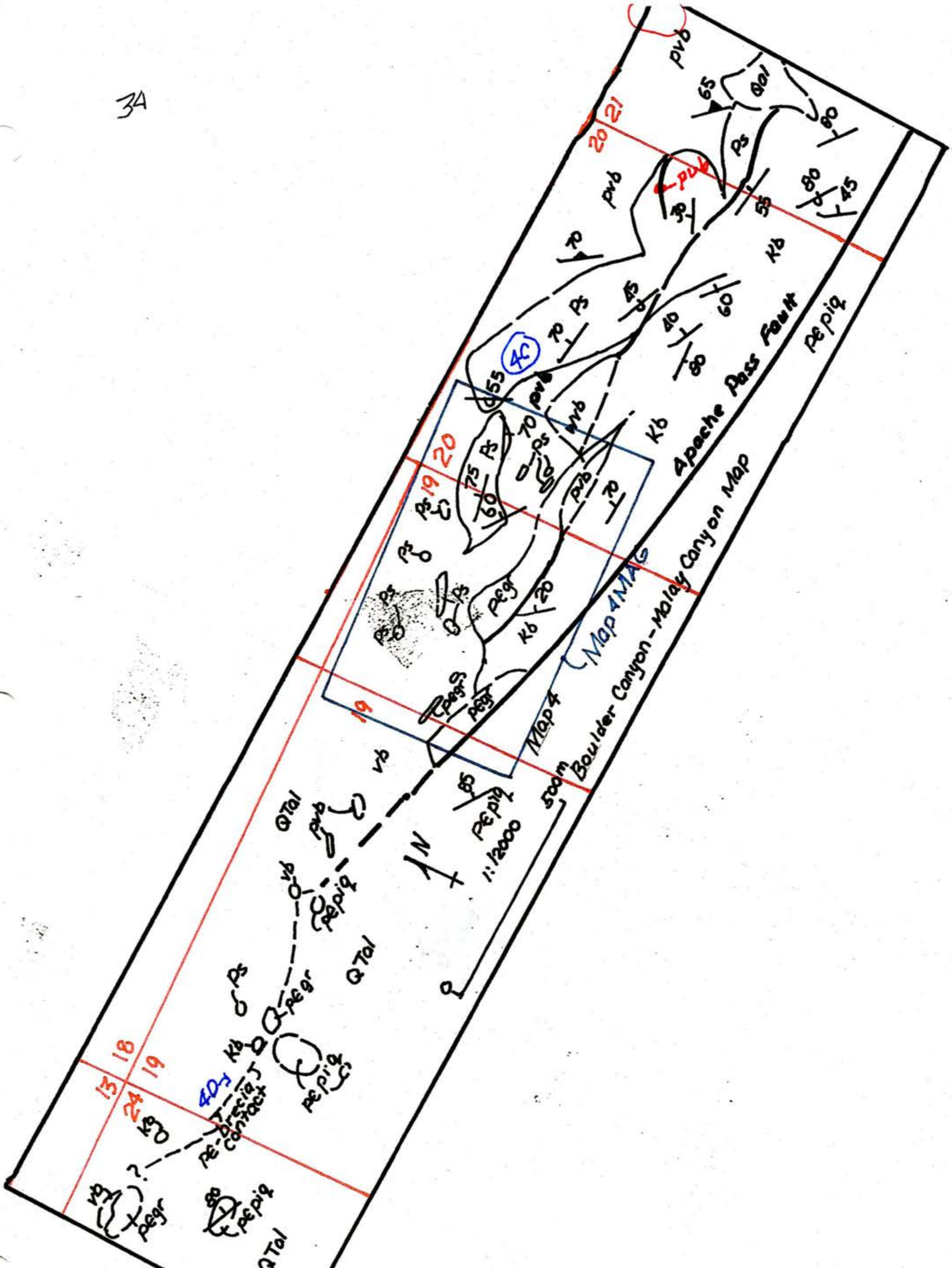
Map 4). This sequence is cut out by the green breccia, going from E to W across it over a 3 km interval (Map 4 The breccia at the west end of this traverse finally crosses the Apache Pass fault and cuts into the granite south of it.

the most complex part of it has been blown up 2X to 1:6000 to make

4MAG Map Map 4MAG

Starting at the easternmost boundary of Map ~~3~~ 4

~~Moving west,~~ the green breccia has cut down through the Paleozoic sediments, wrapped around them, and then cut back ESE about 1 km in a long breccia dike, leaving a giant outcrop of Paleozoic sediments at


Apache Pass Fault
Boulder Canyon - Malay Canyon Map
Map 4
Map 4 MAG
500m
N
4C
4D
QTal
Kb
pvb
Ps
pegr
PЄpiq
PЄ breccia contact

location 4C on Map 4. The block is circa 1.0 X 0.3 km and was nearly totally detached from the southern edge of the wall complex.

This nearly freed block of limestone is in the same state as the boss of Pinal quartzite nearly freed into the green breccia on the north contact of the green breccia body as described above.

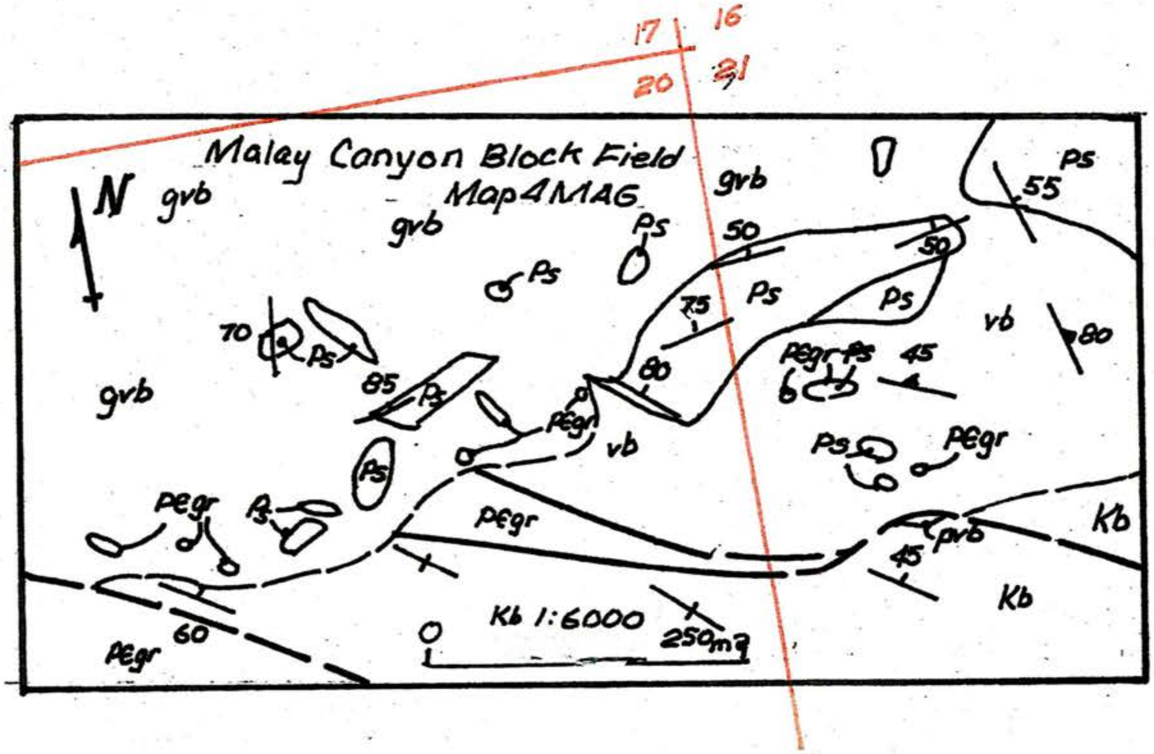
In the northeast side of this block a small dike of purple breccia cuts into it, beginning the process of cutting up this block in its turn.

The breccia cuts more and more to the south through the sedimentary units as the observer goes west from location ~~B3~~ 4C in Map ~~3~~ 4 until, over a 0.5 km interval, it cuts down to and through the Apache Pass fault. In this interval the breccia contacts a large exposure of probable Precambrian granite (not rapakivi) faulted into the sedimentary sequence before breccia intrusion.

Disruption of the sedimentary sequence and the granite has produced a large number of limestone and granite blocks to 250 m size, in a breccia matrix, producing the Maley Canyon block field. This dispersed group of blocks is analogous to a field of near-contact xenoliths in an liquid igneous pluton.

MAP 4 MAG

Map is a 2x (1:6000) magnification of the central part of Map 4, included to clarify presentation ~~on~~ of this area. The ~~figure~~ map shows that ~~the~~ this Maley Canyon block field contains ten large blocks of Paleozoic limestone from 25 to 250 m long, and seven blocks of Precambrian granite to 100 m long. There are in addition a great many smaller blocks, especially of the granite, too small to show at this scale. The blocks of both lithologies are dispersed in green breccia and separated from each other; the original stratigraphy and structures ~~are~~ were destroyed. The blocks were evidently stirred in the fluidized system of the green breccia as it intruded. Contacts of individual blocks


17
16
20
21
Maley Canyon Block Field
Map4MAG
N
gvb
Ps
50
55
70
85
75
80
45
pegr
vb
Kb
pvb
60
Kb 1:6000
0
250m

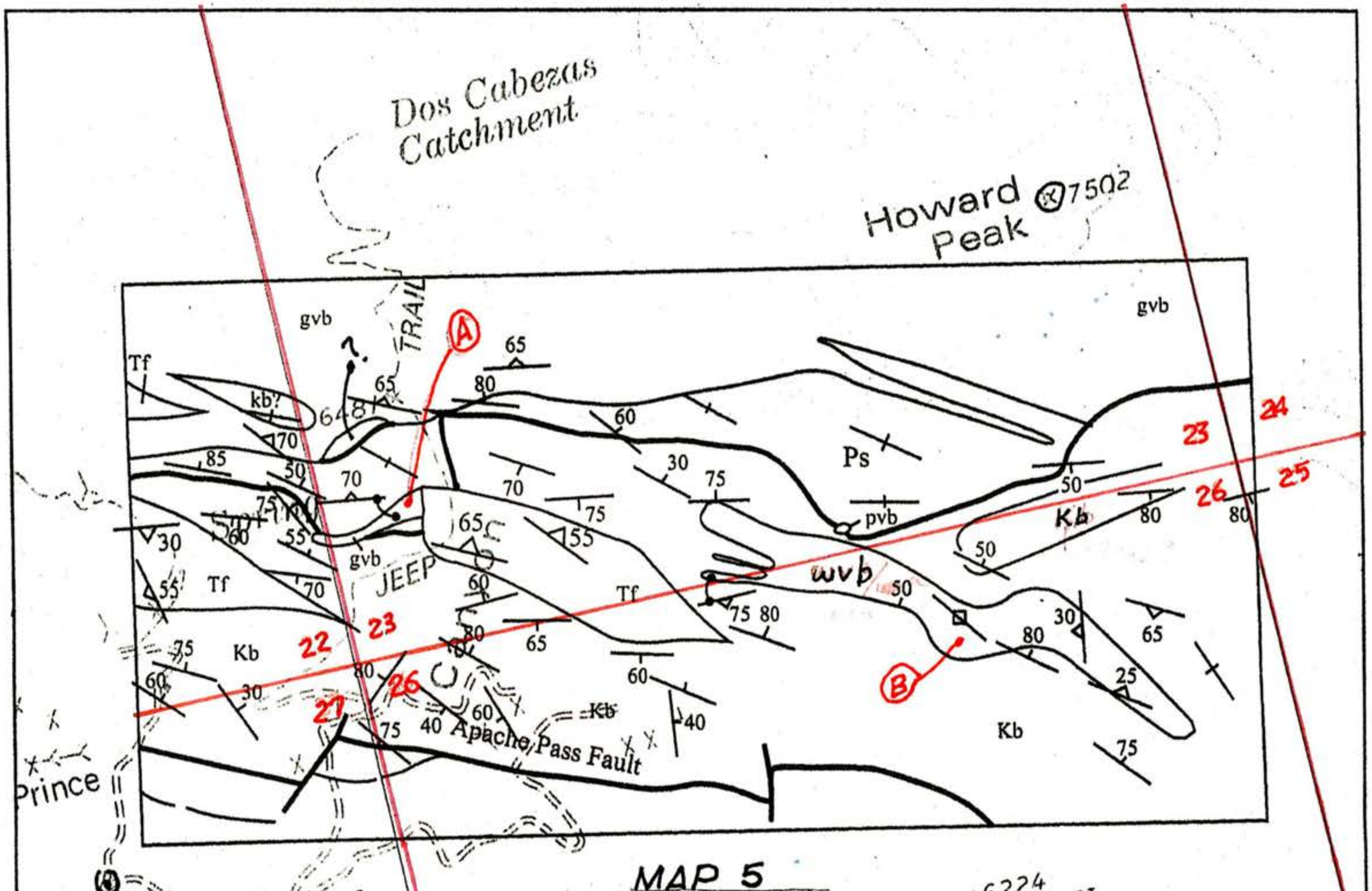
with the green breccia here are often exposed and are always tight and irregular. They are never faults.

The western third of the contact in Map 4. shows the breccia in contact with the Precambrian granite or quartzite originally south of the Apache Pass fault. The exact southern contact between the green breccia and the granite is exposed in a wash, located at point 40 in Map 4. The granite is not the rapakivi type which dominates exposures south of the fault.

Blocks of cherty brown limestone, granite, and shale typically 10-20 m long lie in the green breccia just north of the contact in the western part of Map 4A; these are not found more than 100 m or so into the breccia. They evidently are the last scraps of the sedimentary terrane which originally lay north of the Apache Pass fault in this interval and which was wholly disrupted by the intrusion of the breccia. Two kilometers further west coherent Bisbee shale and the trace of the Apache Pass fault appear north of the fault again (Drewes, 1986).

THE EASTERN ZONE OF THE SOUTHERN CONTACT SEGMENT – BEAN CANYON TO WOOD CANYON

At the eastern end of the southern contact of the green breccia (Map a, Map 5) breccia dikes and pods of many sizes intrude the southern wall of the complex, and the main green breccia body cuts off structures in the Apache Pass fault zone. Here the breccia's south wall is a sedimentary sequence about 1 km wide, composed of Bisbee strata cut off on the south by the Apache Pass fault, and faulted against cherty limestone of the Paleozoic sediments in the north. The sediments in turn are intruded by the green breccia. For example, a circa 100 meter long green breccia dike



MAP 5

Howard Canyon - Howard Peak Map

1:12000

0 ——— 500m

Sections 22, 23, 24, 25, 26, 27
T14S R27E

was intruded along a fault just north of the word "Jeep" on the base map at Location A.

WHITE BRECCIA DIKE CUTTING BISBEE GROUP IN SOUTH CONTACT ZONE

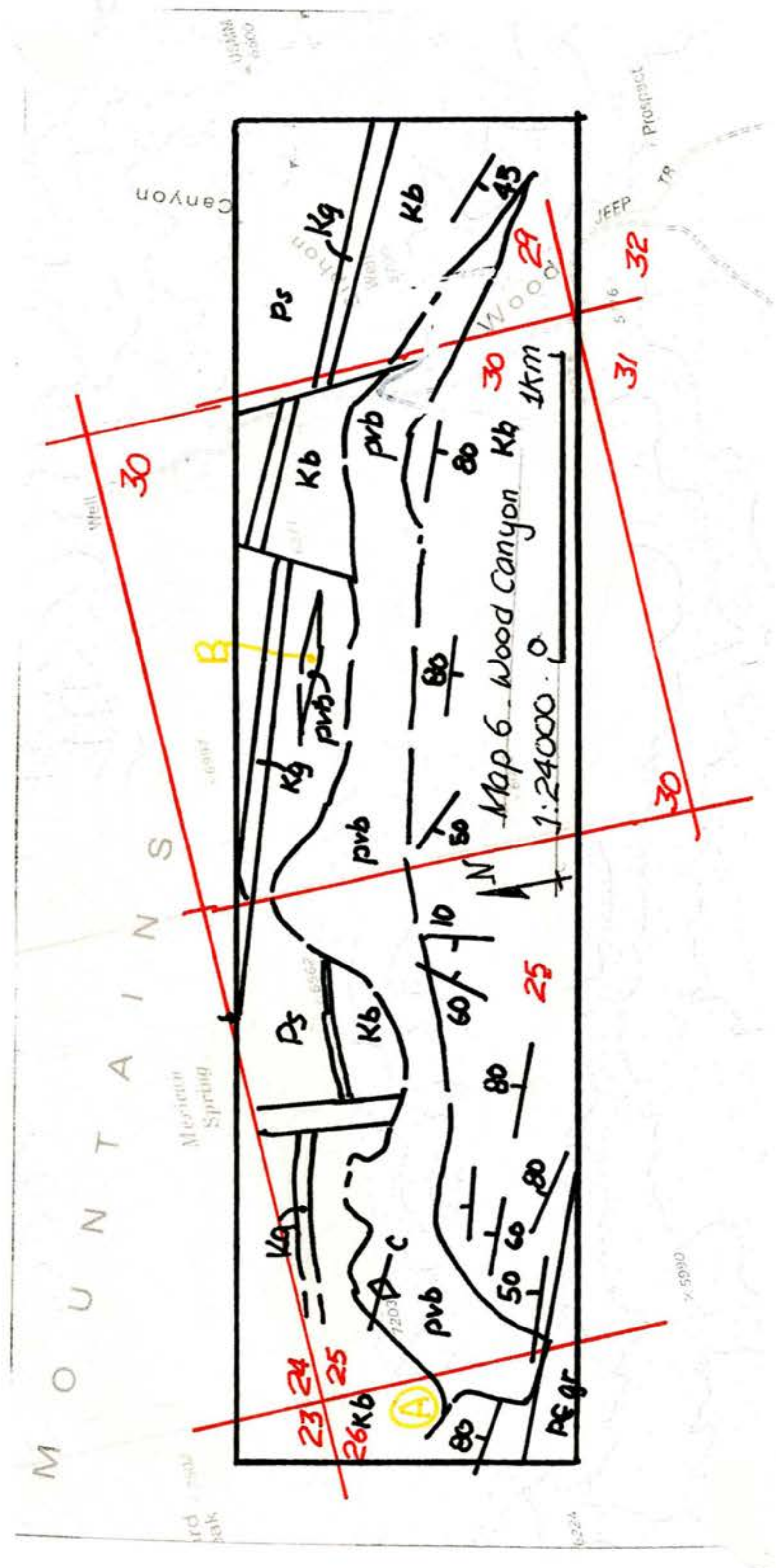
A 1 km long by 50 m wide dike of white lithic breccia cuts the Bisbee Group shale at location B in Map 5 within the Apache Pass fault zone. This dike shows strong vertically-dipping clast foliation in many places. Contacts are vertical to moderate north dipping and often clearly exposed. Parts of the body are nonbrecciated, and are feldspar-phyric white aphanite identical to rock in the magmatic felsite plugs (Tf) just west of the dike. The dike is evidently a breccia facies of the felsite.

GIANT PURPLE BRECCIA DIKE CUTTING BISBEE GROUP

Map a

A giant dike of purple lithic breccia, 4 km long by 100-500 m wide, outcrops between Howell Peak and Wood Canyon (Map a, Map 6). It lies entirely within the Bisbee Group shale and sandstone north of the Apache Pass fault. Much of it is obscured by talus but the contact between the breccia and the Bisbee shale can be seen in several places and is always a knife-sharp and unbroken one. It is not a fault. At its western end the dike cuts down to the Apache Pass fault, but does not appear to cross it. It is younger than the fault.

From this western end several 1m wide dikes of aphanitic purple micro-breccia cut the wall rock (location A on Map 6).


Map 6 Wood Canyon
1:24000
0
1Km
N
MOUNTAINS
Canyon
Wood
Mexican Spring
JEEP
Prospect
A
B
Ps
Kg
Kb
pvb
P€gr
23
24
25
26
29
30
31
32

The main body has occasional clast foliation defined by both planar clasts of purple aphanite and locally by planar fragments of Bisbee shale.

A second smaller dike of purple breccia about 0.7km long and 50m wide lies north of the first, near location B in Map 6.

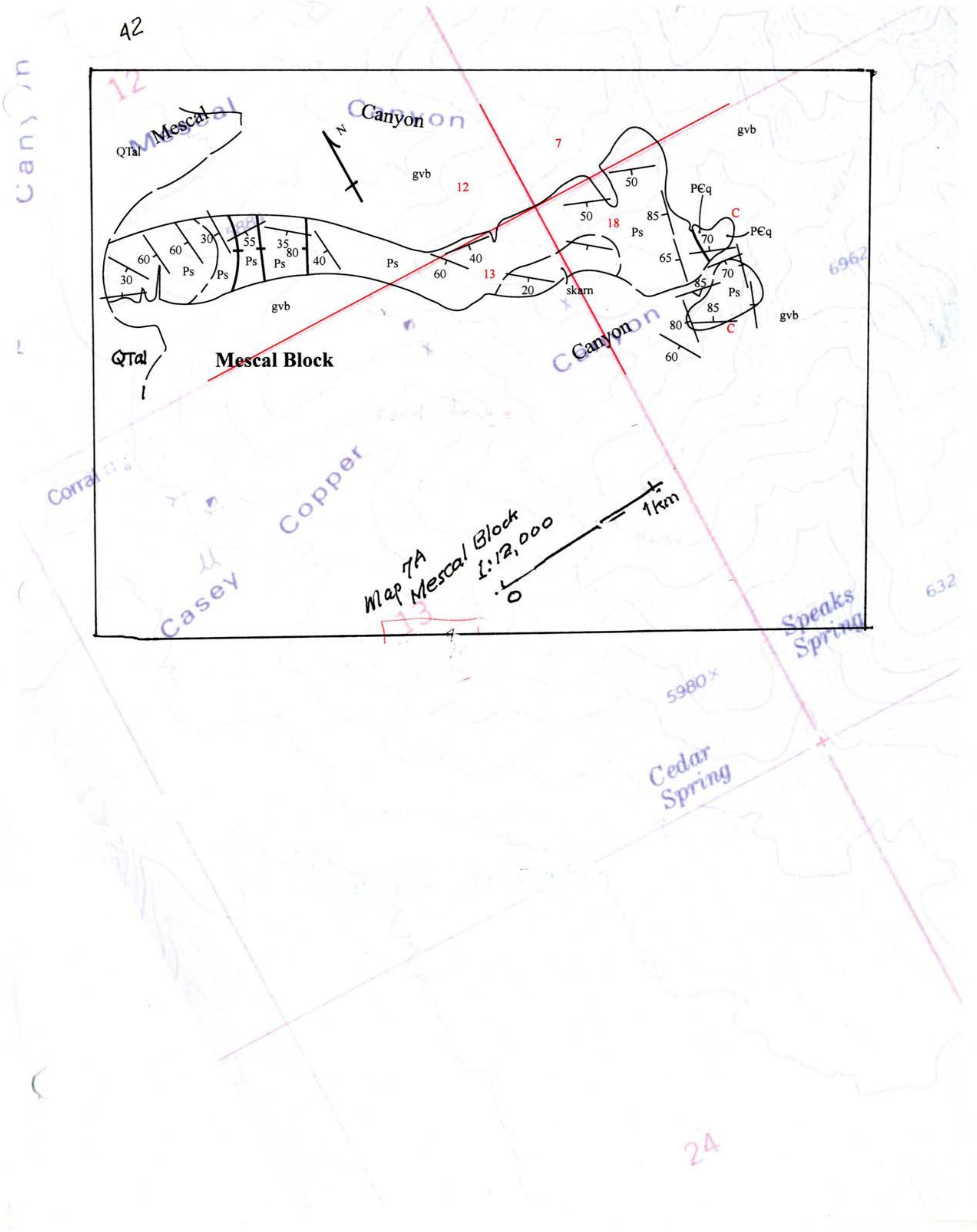
INTERNAL FEATURES OF THE CENTRAL PART OF THE BRECCIA COMPLEX: FREE GIANT BLOCKS AND BLOCK FIELDS

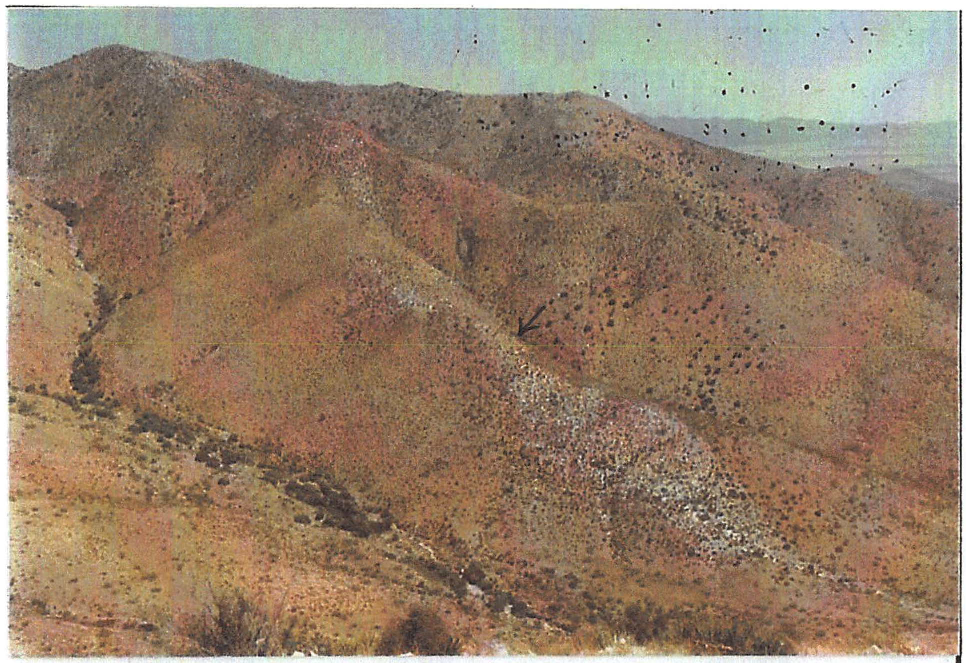
INTRODUCTION

In addition to the partially or wholly freed blocks already described above along the edges of the breccia complex, the central part of the breccia complex (Map a) contains four included giant blocks 200 to 3000 m in maximum dimension, surrounded by green breccia and unattached to any wall segments. I call them <u>free blocks</u>. All four free blocks have block fields associated with them. The contacts of these blocks with the green breccia are always unfaulted, and usually steeply dipping.

THE MESCAL BLOCK

The largest of these four giant blocks crops out in the ridge just east of Mescal Canyon (Map a, Map 7A, Picture 12 (see also Erickson 1968b) after which it is named. The block is 3.5 km long by ~200 m wide, broadening to 400 m at its eastern end. It is almost wholly composed of Paleozoic limestones and shales and sandstone. It is cut by several internal faults which strike roughly normal to the long axis of the block and predate the block formation.


Mescal
Canyon
N
QTal
gvb
12
7
18
13
Ps
PЄq
C
skarn
Canyon
Mescal Block
QTal
Map 7A
Mescal Block
1:12,000
0
1km
Corral
Copper
Casey
Speaks Spring
Cedar Spring
5980
6962
632
24



Picture 12

White band of the Mescal block; surrounded by breccia.

Along the southeastern border of the block magnetite rich skarns are present; future investigators should note that these masses of magnetite will disturb compass readings.

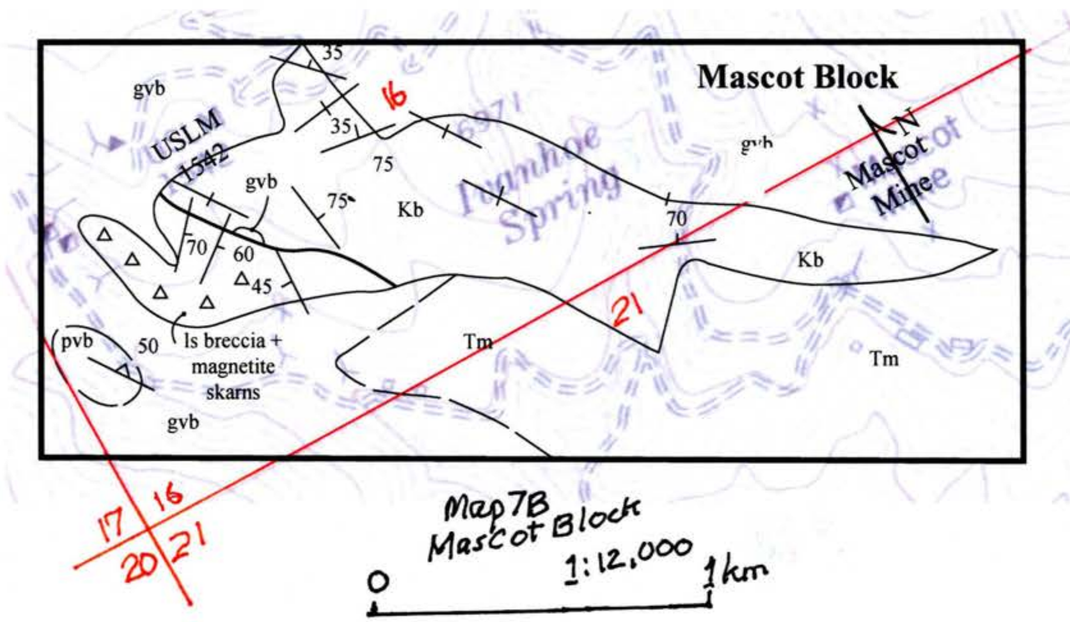
At the west end of the south contact breccia dikes intrude the limestone, and locally the limestone itself is brecciated. The contact is always sharp and never a fault.

The Mescal block provides the best example of a surprising situation; it and the other Free giant blocks have survived sinking in a very energetic fluidized system without breaking up into a mass of fragments. Evidently the large blocks were supported by the streaming fragment bed as they slowly sank into it. No doubt they would have eventually broken up. This phenomenon is especially striking here, since the Mescal block is crossed by several presumably once-active faults.

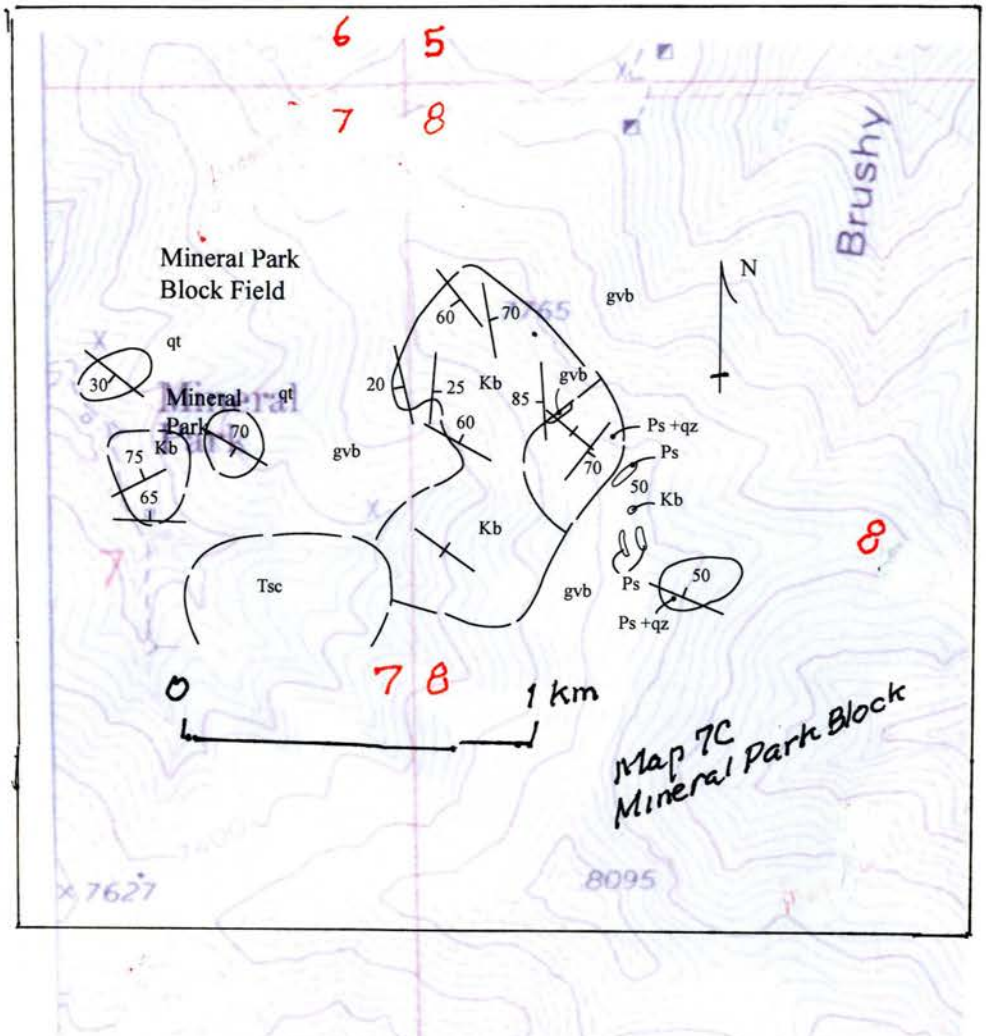
The giant quartzite block in the Premier kimberlite pipe described by Dawson (1980) had sunk several hundred meters below its original stratigraphic level but not broken up, in the same manner.

THE MASCOT BLOCK

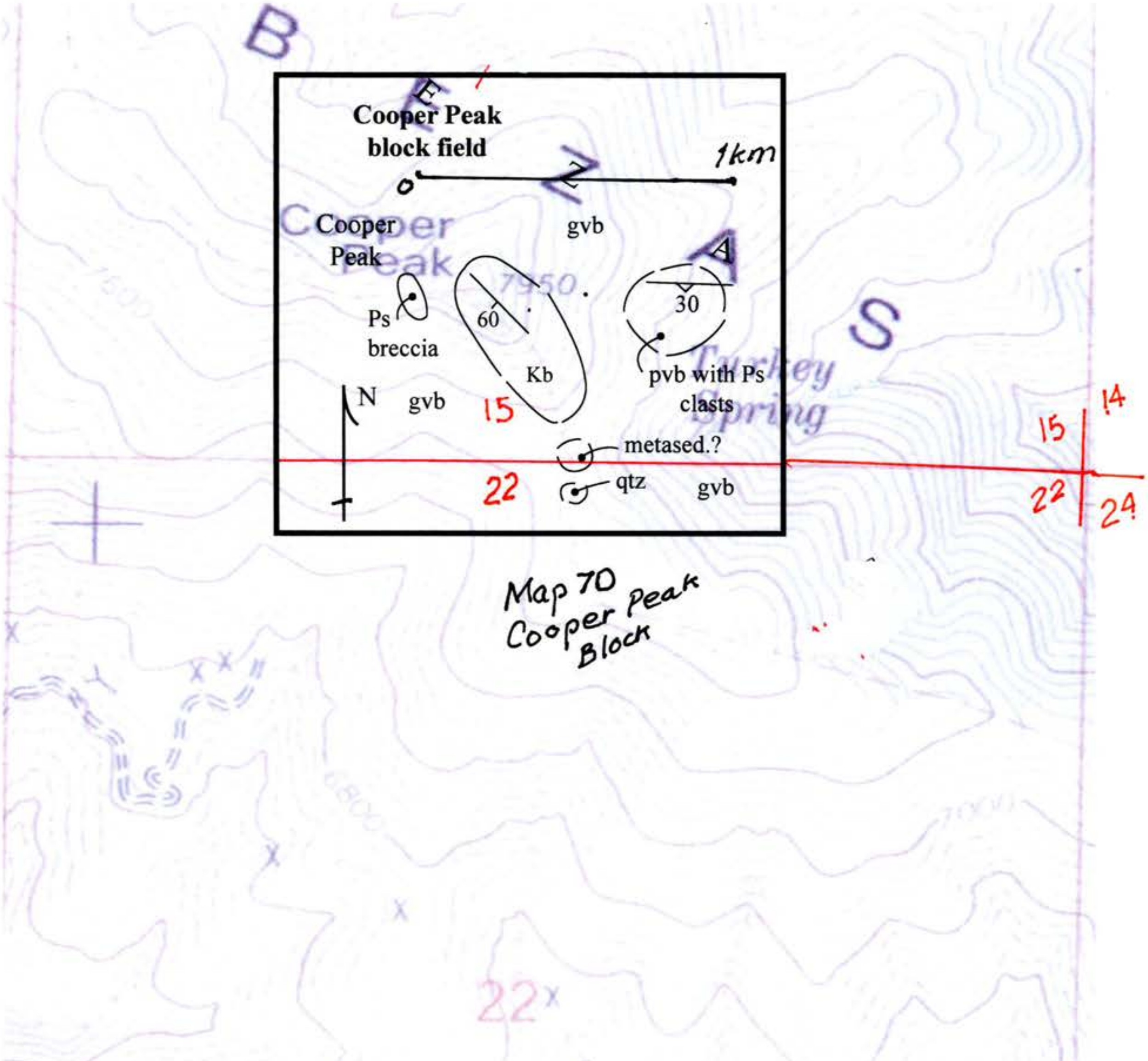
This block is 3 km long by 300 m wide (Map a, Map 7B). It lies 1 km north of the Apache Pass fault zone, and is intruded on the south by the Mascot stock. Both the stock and the block are named here after the Mascot mine, developed in these rocks. The central and eastern part of the block are composed of siltstone and sandstone of the Bisbee Group. The western third of the block is composed of an unnamed recrystallized marble, separated from the Bisbee rocks by a local fault contained within the block. A small dike of green breccia intrudes part of this fault. The



Map 7B
Mascot Block
1:12,000
0
1 km


6
5
7
8
Brushy
Mineral Park
Block Field
N
gvb
60
70
Kb
20
25
85
qt
30
Mineral
Park
70
Kb
75
65
gvb
60
70
Ps +qz
Ps
50
Kb
Kb
8
Tsc
gvb
Ps
50
Ps +qz
0
7
8
1 km
Map 7C
Mineral Park Block
7627
8095

Picture 13
Aphanitic purple breccia intrudes grey limestone; border of Mineral Park block



Map 70
Cooper Peak
Block

The western part of the breccia complex is largely separated geologically from the rest of it by the 64 Ma Silver Camp stock, (Erickson, 1969) and separated topographically by the Silver Camp wind gap eroded in the main ridge of the Dos Cabezas mountains (Map a). Geologically the western breccias are texturally similar to the green ones just described, but are almost all a dark purple in color. These are the purple breccias. They do not display evidence of significant metamorphism, unlike the green breccias.

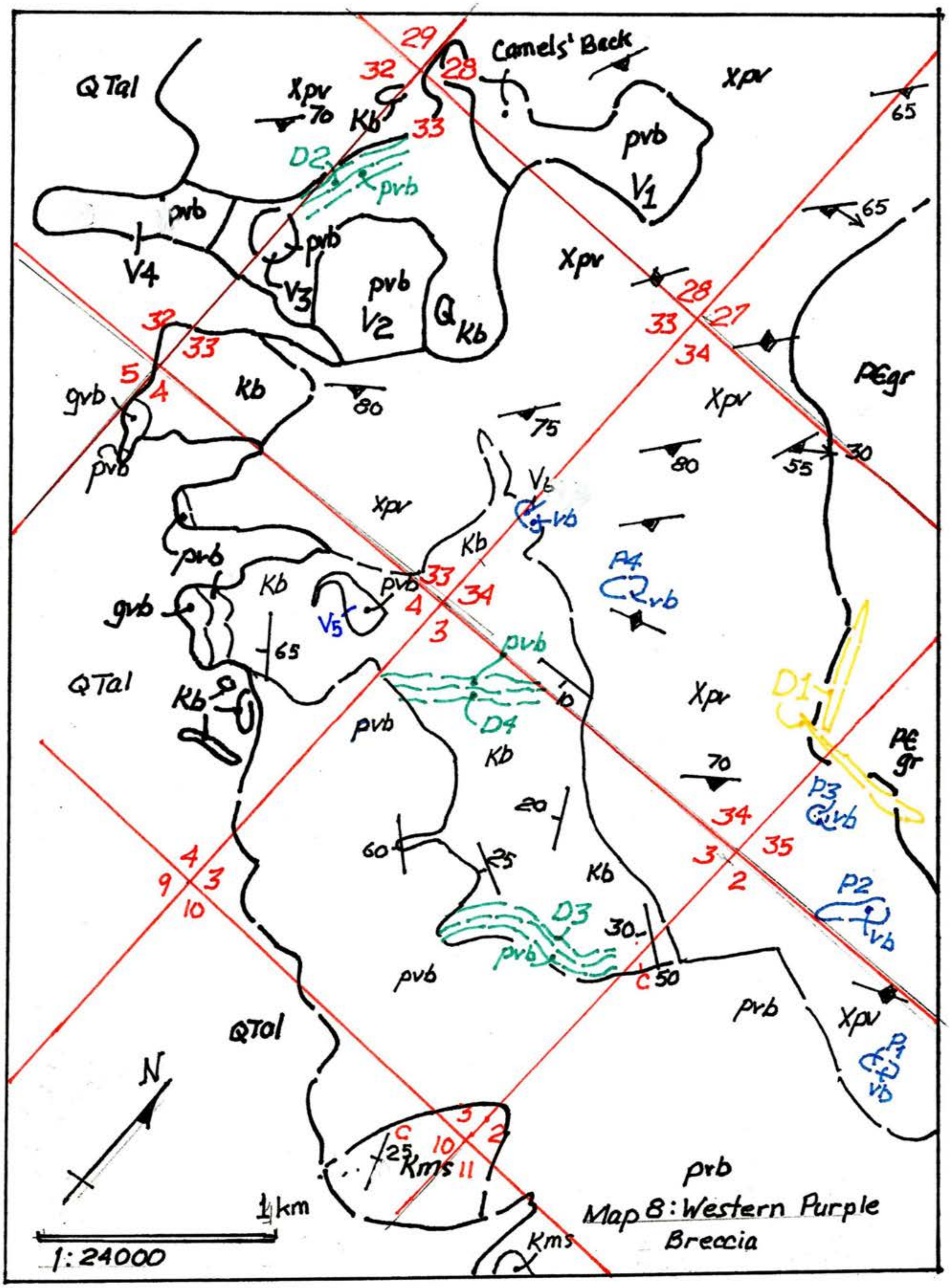
WALL ROCK-BRECCIA FIELD RELATIONSHIPS IN THE WESTERN PART OF THE BRECCIA COMPLEX

The wall units intruded by the breccia in this part of the complex are arranged as follows (Map a, Map 8). West of the Silver Camp stock, Precambrian Pinal Schist metavolcanics, now phyllites, are intruded by Precambrian Polecat granite. These are overlain just north of the Apache Pass fault zone by a south-dipping homoclinal slab of Cretaceous Bisbee Group shales, limestones, and conglomerates (Map a and Map 8); see also Erickson and Drewes, 1984.)

These wall units are intruded by a large number of dikes and pods of dark purple volcanic breccia and nonbrecciated purple aphanites.

Green and white breccia bodies are uncommon though present.

At the western end of the breccia complex, Bisbee sediments are intruded by six separate equant bodies of purple lithic breccia (locations V1- V6, Map 8) described below, the largest of which is the 0.5 X 1.5 km breccia neck of the Camel's Back peak (at V1) and by two dikes of purple


Camels' Back
QTal
Xpv
Kb
pvb
V1
V2
V3
V4
V5
V6
D1
D2
D3
D4
P1
P2
P3
P4
vb
gvb
Q Kb
PЄgr
QTal
Kms
N
1 km
1:24000
Map 8: Western Purple
Breccia

breccia about 1 km long (at D1). Within the Pinal phyllites near these latter dikes are four small bodies of intrusive breccia composed entirely of Pinal phyllite fragments (locations P1-P4, Map 8).

At location D2 on Map 8, exposure of the main body of purple breccia begins. This point locates the north end of a largely buried 1.5 km long and E- striking dike of purple breccia that widens at its eastern end and rapidly expands as the observer moves south to become a very large irregularly shaped mass of purple breccia roughly 3.0 X 1.5 km in maximum dimension, about 2 km^2 in area.

Approximately 10 km of the northern contact between this body and its walls of Bisbee Group rocks and Precambrian schist and granite are well exposed and can be mapped in detail. The contact can be located within a meter or two in most places and occasionally is clearly exposed. The contact is very tight and unbroken and irregular in strike and dip, and is not faulted; it is clearly intrusive.

In three places (locations D2, D3 and D4 in Map 8) the Bisbee Group beyond the main breccia contact is intruded by extensive sets of sills and dikes of aphanitic purple breccia easily mistaken in hand specimen for a magmatic aphanite. (Their fundamental fragmental nature is clear in thin section). These units show complex interconnections and contain deformed xenoliths of Bisbee rocks Their petrography is described below. These sill/dike systems have map patterns too complex to show on the scale of Map 8 and are represented on it by a stylized dash pattern.

PETROGRAPHY OF THE PURPLE BRECCIAS

move to next page -

The purple breccia in a pure state is an isotropic unbedded matrix-supported lithic volcanic breccia, composed of circa 50-90% of dark purple aphyric aphanitic fragmental matrix, usually colored a different tint of purple than the megascopic fragments (Picture 3 Clasts are typically1-10 cm but range from <1mm to several dm in size in local examples. They are generally angular and equant, but are occasionally planar and/or rounded. Original microphenocrysts in the clasts were plagioclase and amphiboles; plagioclase is near An 15-30 and former amphibole is represented by pseudomorphic aggregates of hematite, sericite, and sometimes chlorite which together have a relict euhedral amphibole outline. Quartz and/or Kspar phenocrysts are absent from the clast and matrix assemblages.

The breccia's matrix, examined under a petrographic microscope, is a mass of small mineral and rock fragments grading down to a birefringent mosaic of irresolvable units. No glass is present, nor any textures suggesting recrystallization of pumice, shards, or eutaxites. In thin section the clasts and matrix are usually very highly altered to sericite, carbonate, epidote, and hematite.

There is an overall unity to the purple breccia exposures that allow it to be used as a single map unit. It does tend to vary, however, from one place to another in exact matrix color, in fragment size, shape, color, and proportion, and in type of exotic fragments. It is not clear how many discrete purple breccia bodies there are, but there are a great many; a large number of separate bodies surrounded by wall units are present, and local internal contacts in larger bodies such as that occupying half of Map 8 are occasionally seen. The purple breccia as a whole is a complex unit.

A great many small bodies of the purple breccia cut units of the green or white breccia. all through the breccia body.

of rock types

The purple breccia also commonly contains some % of fragments not found in the walls, at least at the present erosional level. The most common variation of this sort involves incorporation of several % of clasts of a white to yellow aphyric aphanite.

Near contacts the breccia commonly contains sparse to abundant fragments of wall units. For example, the dike located at D2 in Map 8 contains about 20% fragments of Paleozoic limestone to 1 dm. In another example, along the southern contact of the breccia where it cuts Glance Conglomerate of the Bisbee Group, the purple breccia contains abundant fragments of limestone to 5 cm. Also, in some bodies the purple breccia is filled with small clasts of granite and constituent minerals from the granites beneath it.

pic 14

INTERNAL STRUCTURE OF THE PURPLE BRECCIA

In the general case, the purple breccia fragments, like those in the green breccia, have no overall structure; they have no preferred orientation and the outcrops have no stratigraphy. Some groups of fragments do, however, display clast or layer foliation, just as in the green breccia. The purple breccia, like the green, was intruded as a fluidized mass in which local orientation of clasts was sometimes observed.

POSTBRECCIA MAGMATIC INTRUSIVES

Picture 14

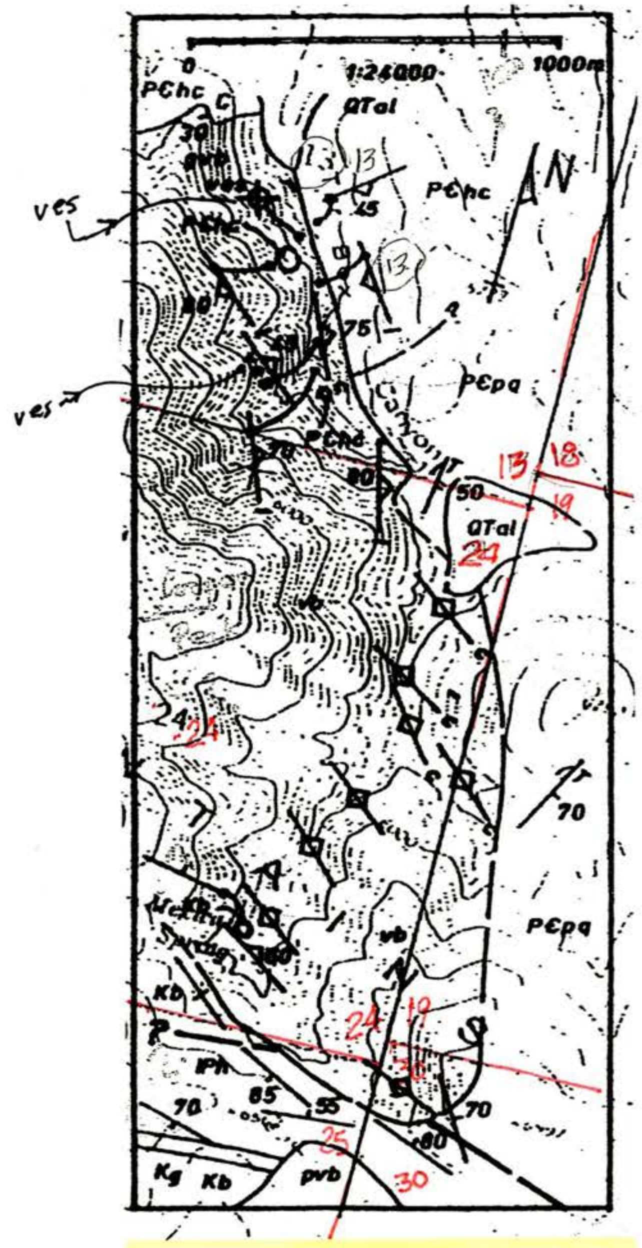
Purple breccia containing abundant limestone clasts. Rucksack for scale.

pvb with ~20% ls clasts –

The purple breccias have been intruded by innumerable magmatic dikes and irregularly shaped bodies of green and purple aphanitic and phyric aphanitic rocks which are oligoclase phyric aphanites where their plagioclase composition could be determined. Typically they are a minor component but locally, as in the vicinity of Silver Peak (Map a) they are as abundant as the breccia component or even dominate. They are usually extremely altered, like the breccias, so that no amphibole phenocrysts survive and all parts show extensive development of epidote, sericite, and carbonate.

THE EASTERN PART OF THE BRECCIA COMPLEX BETWEEN BOTA CHIQUITA SPRING, MEXICAN SPRING, AND COOPER PEAK;

Map 9 shows the exposure area of an internally uniform body of lithic-crystal-vitric breccia composed of approximately 50% 1-2 cm clasts of various dark to white aphanites in a matrix of broken plagioclase, quartz, and sanidine crystals (sanidine ID'd by small 2V) in Kspar and finer-grained ash or shards. This is typical white breccia (Picture 4) No blocks of older units are found within it. The body shows no eutaxitic texture and no stratigraphy – stream sections show no layering except near contacts where it commonly displays layer foliation. A preferred orientation to the compacted clasts (?) is clear in most thin sections, but not in outcrop. In sections the proportion of crystals to clastic matrix varies greatly, from perhaps 30 to 95%. Primary biotite has been replaced by a pseudomorphic aggregate of muscovite, chlorite, sphene, and secondary biotite. Metamorphic biotite



Map 9: Tar Box Canyon to Mexican Spring

and epidote produced during autometamorphism of the complex are common. (The contact of this white breccia with the main body of green breccia ~~in western~~ has not been mapped.)

GENESIS OF THE BRECCIA COMPLEX

The green, purple, and white breccias have many characteristics in common. They are usually structurally isotropic bodies, composed dominantely of fragments of igneous aphanites, together with fragments of the sedimentary rock units found in the Apache Pass fault zone, Pinal Schist and Bear Canyon units, and coarse-grained Precambrian granite. Considering the breccia body as a whole, it has intrusive contacts with development of fringing dikes. The green breccias have giant xenolithic blocks and block fields of smaller blocks, no longer attached to the walls of the complex. The green and purple breccias have local zones of layer and clast foliation.

The evidence strongly suggests a model in which the breccias were produced by gas expansion fracturing and fragmentation of preexistent rock units, followed by fluidization of the fragments and intrusion of the fragment bed into its roof and walls, accompanied by subsidence of giant roof blocks. The breccia mass is then essentially a pyroclastic stock or breccia stock, analogous in its major characteristics to a magmatic pluton. The magmatic fluid is not a coherent silicate liquid but a 2-phase fluidized system of solid clasts in gas.

FRAGMENTATION: SOURCE OF CLASTS

Burnham (1985) has described a reasonable mechanism by which sudden volatile release from a crystallizing pluton undergoing second boiling would shatter large masses of wall rock and leave the resulting breccia amenable to fluidization of the fragments by the remaining volatiles (supercritical water and carbon dioxide) escaping as the pluton continues to crystallize.

Some disintegration of the magma would probably occur in many cases of vigorous frothing and volatile expansion, leading to entrainment of phenocryst crystals from the magma in the volatiles and their incorporation into the breccia. The crystals of beta-quartz and much of the plagioclase in the finer fraction of the green breccia described here probably had this source. Crystals freed and incorporated by this mechanism are found in other intrusive breccias (Bussell and McCourt, 1977; Hughes, 1958; Morris and Knopf, 1967) The final stocks (Silver Camp, Mascot) to intrude the Dos Cabezas breccia complex are quartz diorite and provide a model source for these crystals when partially crystalline. It is possible that these outcropping stocks were, when liquid, and evolving, part of the actual source of the fluidizing gases which built the complex. Other still-buried stocks (Erickson, 1981) may have provided some heat and solids to the process.

FLUIDIZATION

Fluidization is a process in which a gas or liquid is passed through a mass of fragments called a *bed*, buoying up the fragments and allowing them independent motion. The result is a two-phase system that acts as a fluid in all respects, with its own density, viscosity, and so on.

Comprehensive treatments of the phenomenon are given by Leva (1959), Zabrodsky (1966), and Kunii and Levenspiel (1968); a quick overview is given in Wikipedia. An excellent summary of the effects of fluidization in geological processes is given by McCallum (1985)

As clasts repeatedly strike each other, they are ground down and rounded. A continual supply of new fine-grained material is made, and as the fluid breaches the bed surface this new material is said to be carried out or elutriated from the bed.

THE MODEL

Here is the model developed by the author for the genesis of the breccias in the Dos Cabezas mountains. The model cuts roughly NE-SW across the central Dos Cabezas range.

close up

There are five main stages to ~~the model~~ it.

close up

6

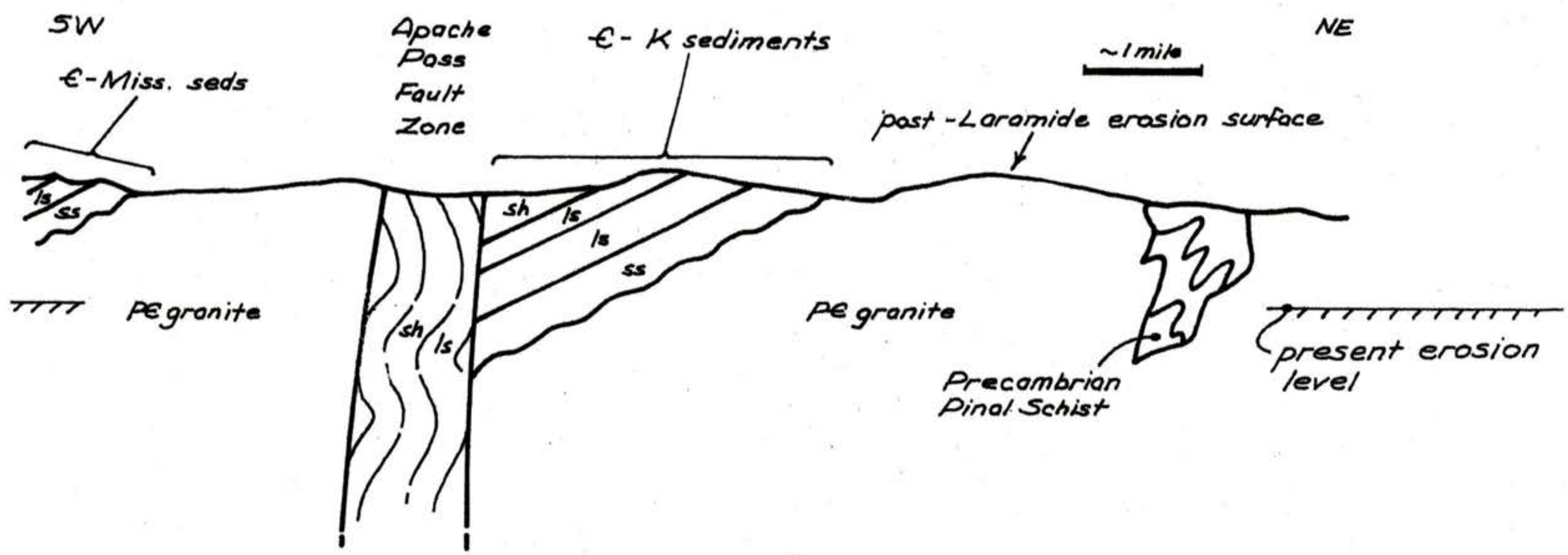
Stage A:

The following material shows a cartoon cross-section of the central Dos Cabezas mountains, in the late Cretaceous, before intrusion of the purple and green breccias. The Apache Pass fault zone is in the center, with Paleozoic limestones, Mesozoic shale, Mesozoic ignimbrites, and Precambrian granite all deformed and fault-bounded within the zone. To the north and south lie Precambrian granite crust. The present erosion level is shown some km distance below the model late Cretaceous surface.

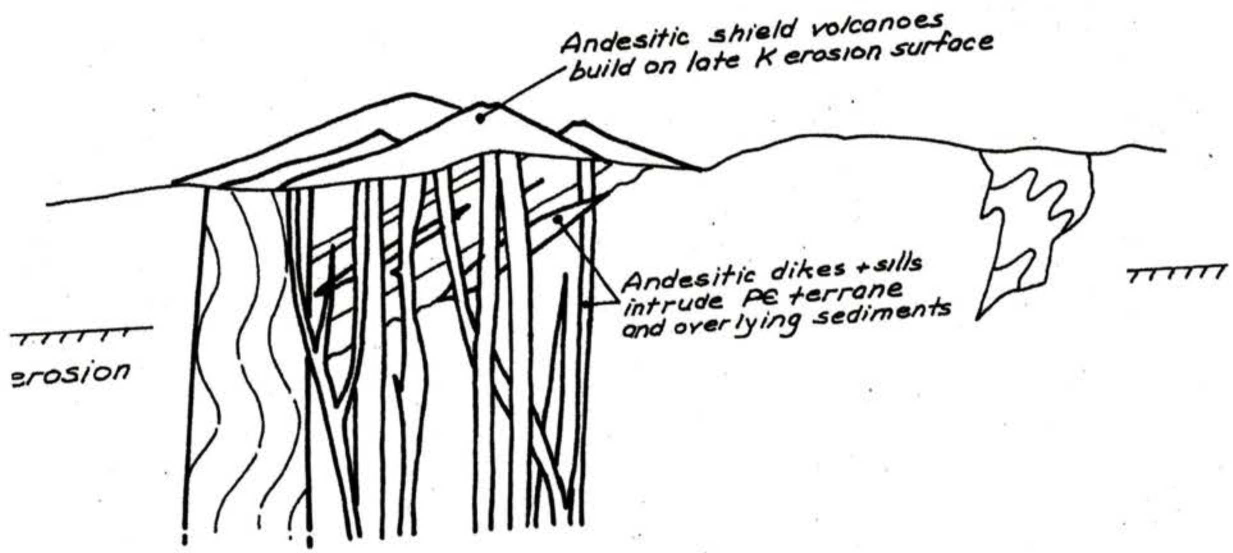
move up

Stage B:

Model Stage A



Model Stage B



62

This drawing shows that Intermediate composition magma has risen up the zone of weakness along the Apache Pass fault. Distribution of its products is modelled after the types of clasts present in the green and purple breccias. An extensive zone of aphanite dikes, plugs, and sills was developed in preexistent units. Some coeval surface eruption probably developed, but low abundance of such rocks in the breccias suggests it was rare. Dense unvesiculated aphanite flows and ignimbrites were probably present.

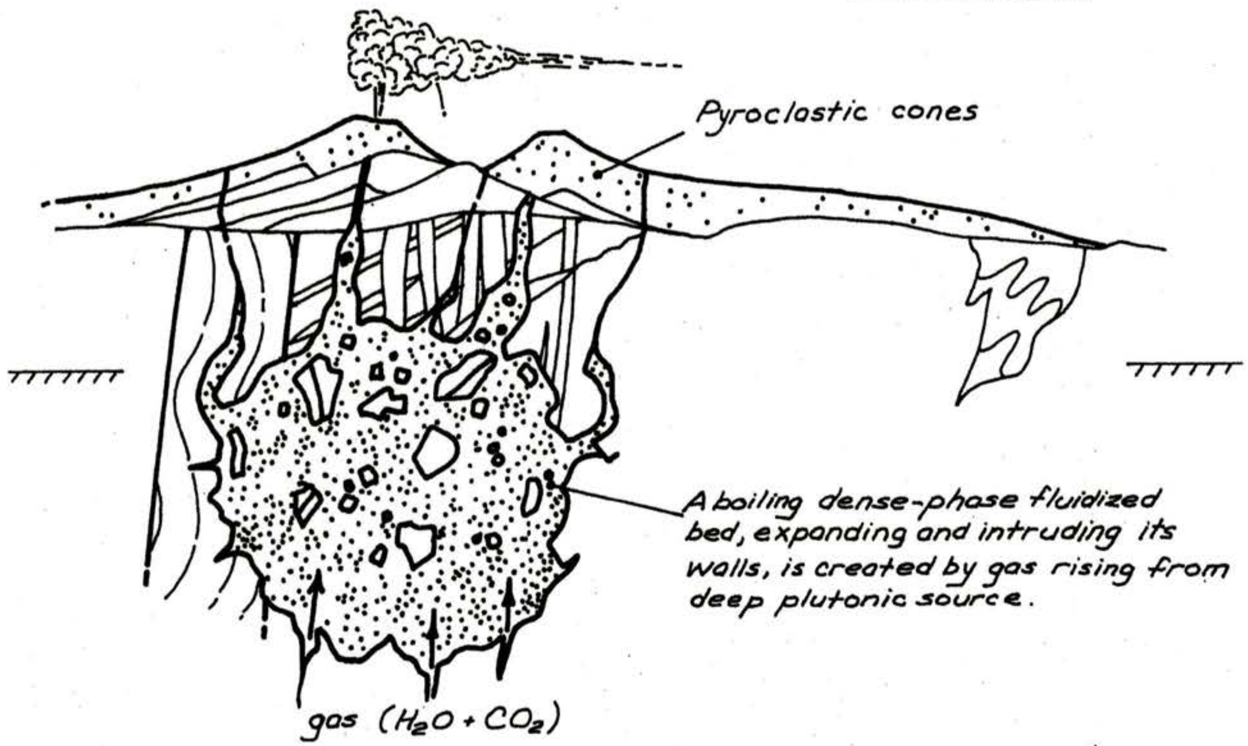
Stage C:

This drawings shows that the aphanite magma has stopped rising and began to crystallize. Following Burnham's (1985) model, volatiles being driven from the main body of crystallizing andesite magma burst through the outer crystalline shell of the pluton, brecciating the preexistent rocks in the roof. After the fracture system formed, continued volatile escape formed a dense-phase fluidized bed from the fragments. The bed mixed, expanded, and intruded its roof and walls. The bed eroded its contacts actively, and giant blocks of wall and roof rocks slowly sank into the bed.

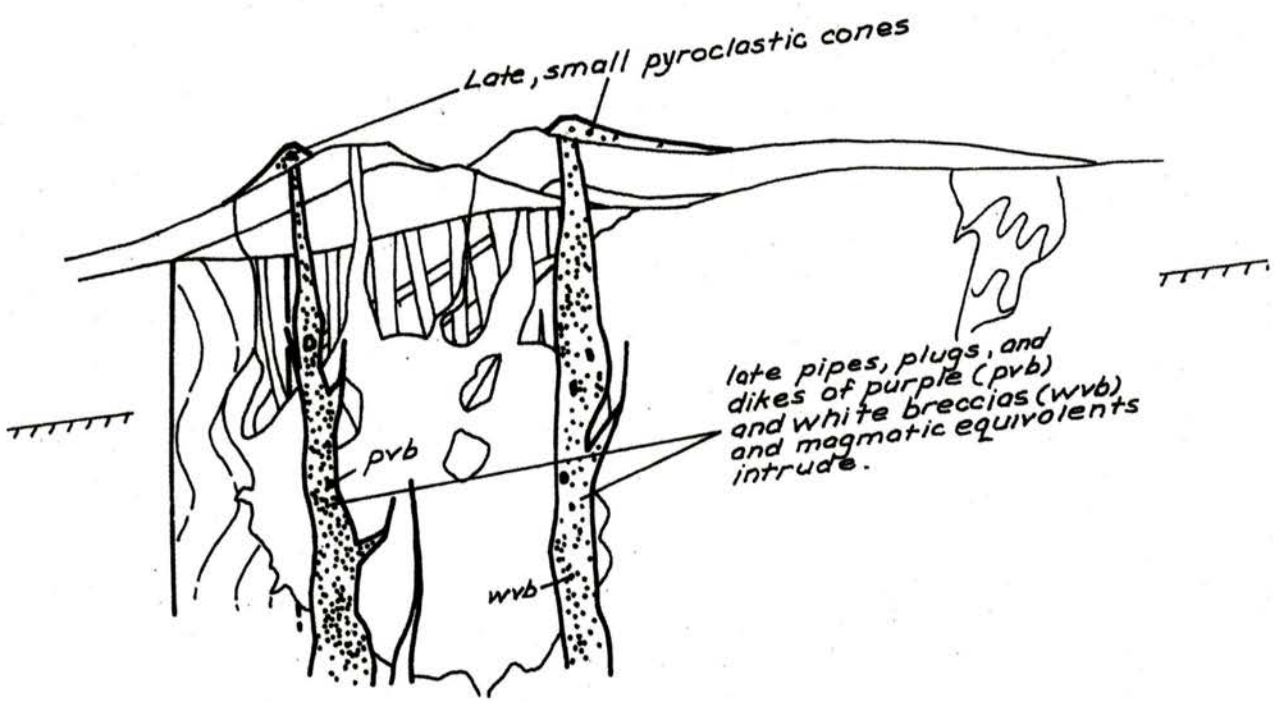
As the volatile source waned, the single giant bed ceased being fluidized. The bed was very hot and underwent extensive autometamorphism, developing extensive sericite and epidote in its inner parts. The main green breccia was developed. The Apache Pass fault was locked and remains so.

This was followed by the formation of the purple breccia. This unit formed in the same manner as the green breccia. Oxidation in this second set of breccias was much stronger than in the green breccia and the highly

Model Stage C



Model Stage D



altered rocks turned purple of various tints due to extensive hematite formation. Overall temperature was lower than during formation of the green breccias, so no epidote formed in the beds.

add on here-!

Stage D:

The next stage in the brecciation was development of small bodies of white breccia, which cuts all the other units. Probably surface pyroclastic deposits built up from the entrained fragments.

TR Stage E This drawing shows the situation when fluidization ended. The degassed source magma rose and intruded the breccias, first with innumerable small magmatic dikes and plugs and then with major magmatic stocks. For modelling purposes we may assume that the modern Silver Camp, Mascot, and Cowboy stocks (Erickson, 1969; 1981; Erickson and Drewes, 1984a) are analogous to those in the model, though perhaps not the actual sources of the breccias.

CONCLUSIONS

This complex is the largest of its kind ever studied, so far as the author is aware. The breccia complex is equivalent in size to many calderas, and provides a model for a different type of subvolcanic activity probably related to pyroclastic eruptions.

The breccia complex is a pyroclastic stock. During it's intrusion it was a 2-phase fluid, a fluidized solid-liquid system, very different in internal character from a silicate magma; nonetheless, its internal structure and contact relationships are exactly analogous to those of a magmatic intrusive. Both show wall intrusion and roof stoping and the presence of

Model Stage E

Intrusion of several quartz diorite stocks in earliest Poleocene ends sequence xenolithic blocks on all scales. Both show bordering dike systems. Both show local internal foliation marked by oriented planar layers of xenoliths and mineral crystals. Both show post-solidification alteration of their original constituents.

ACKNOWLEGEMENTS

I dedicate this work, with great thanks, to the late Dr. Evans Mayo of the University of Arizona Geology department, who introduced the writer to the study of intrusive pyroclastic rocks, and also give great thanks to the late Dr. Paul Damon, also of the University of Arizona Geology department, for suggesting the Dos Cabezas project for my PhD dissertation subject, and for providing financial support for my work from NSF grant GP-3738 and others. Dr. Damon was also instrumental in my receiving 3 consecutive NSF Cooperative Graduate Fellowships. I must also thank Dr. Harald Drewes of the U.S. Geological Survey for encouraging me to publish the geologic map of the Railroad Pass 7.5' quadrangle, (Erickson and Drewes, 1984), where Some of the breccia complex lies, through the offices of the U.S. Geological Survey. Finally, let me thank the late Dr. R. Sillitoe who read and commented on an earlier version of this manuscript, which helped me considerably.

A number of ranchers in the Dos Cabezas area were very helpful. The writer especially wants to thank Mrs. Helen Foster, Mr. and Mrs. Roy Holland, and the late Mr. and Mrs. Ray Wien, all of Dos Cabezas Village, and the late Mrs. Bea Grove of Willcox, Arizona, for their help and support over many years. The Hollands were especially helpful in loaning me a small house trailer to use as a field station in my first years in the mountains. Last, the writer would like to thank the many residents of the

Dos Cabezas range who allowed the writer access to their private lands or otherwise helped him in many ways.

Thanks to Ms. Sarah Padilla who drafted several of the maps

also very much

and

Ms. Lynne Morin who provided excellent copy and editorial work.

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11/25/201