TRGS #15 - Tobacco Root Geological Society 2000

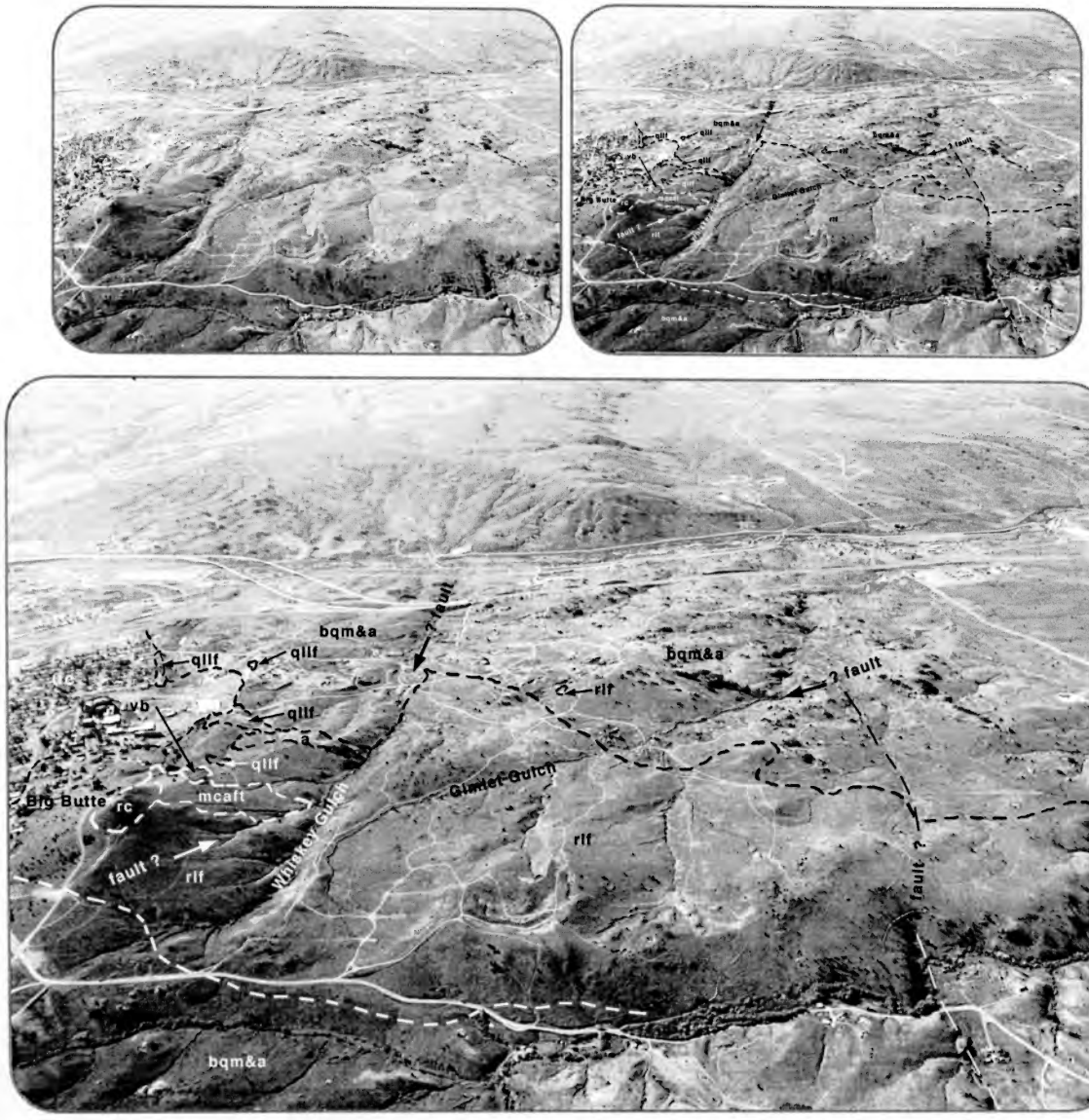
Stereo Picture Guidebook to Big Butte Volcanics

prepared for Tobacco Root Geological Society

by

Hugh Dresser

2000



You are looking southward at Big Butte and its rhyolites.

a = aplite bqm&a = butte quartz monzonite and aplite mcaft = mostly covered ash flow tuff qllf = quartz latite lava flow rc = rhyolite conduit rlf = rhyolite lava flow vb = vent breccia uc = urban cover

Gimlet Gulch and Whiskey Gulch may follow faults, and the Whiskey Gulch fault may offset the Gimlet Gulch fault; however, displacement of the volcanics cannot be demonstrated across either gulch. The courses of the gulches may have been determined by renewed movement on faults that previously offset the underlying "bqm&a" and then merely fractured the overlying volcanics to channel groundwater flow and produce rapid weathering.

Table of Contents

Page

Abstract & Acknowledgements ---------- 1
Big Butte Volcanics ---------- 2-3
Viewing Stereo Images ---------- 4
Oblique Photomap View Northwest ---------- 5
Route of Big Butte volcanics field trip ---------- 6
Stop 1 area ---------- 7-10
- Eutaxitic Texture ---------- 7
- Welded Tuff ---------- 8
- Tuff Dike ---------- 9
- Photomicrographs of Tuff Dike ---------- 10

Stop 2 area ---------- 11-14
- Inclined Columnar Joints ---------- 11
- Photomicrographs Columnar Jointed Dike ---------- 12
- Columnar Jointed Dike ---------- 13
- Dike Foliation ---------- 14

Stop 3 area ---------- 15-20
- Rhyolite Breccia ---------- 15-16
- Andesite Dike Cuts Granoaplite ---------- 17-18
- Quartz Latite Lava Flow ---------- 19
- Foliation & Photomicrographs Quartz Latite ---------- 20

Stop 4 area ---------- 21-22
- Oblique Photomap View North ---------- 21
- Obsidian - Photomicrographs ---------- 22

Stop 5 area ---------- 23-26
- Shattered Rhyolite ---------- 23
- Rhyolite Breccia ---------- 24
- Variable Foliation ---------- 25-26

Stop 6 area ---------- 27-32
- Steeply Dipping Foliation ---------- 27
- Rhyolite Breccia - Photomicrographs ---------- 28
- Chilled Borders Around Breccia Clasts ---------- 29
- Stretched Rhyolite Fragments ---------- 30
- Aligned Rhyolite Fragments and Striated Rhyolite ---------- 31
- Fault Cuts Rhyolite Breccia ---------- 32

Stop 7 area ---------- 33-42
- Consistent Foliation & Photomicrographs ---------- 33
- Consistent Foliation ---------- 34
- Curved Foliation ---------- 35
- Foliation Defined by Rhyolite Clots & Ribs ---------- 36
- Foliation Defined by Clots, Lenses, and Lamellae ---------- 37
- Foliation Defined by Clots ---------- 38

Table of Contents

Page

Aligned Clots Define Foliation ---------- 39
Aligned Clots ---------- 40
Rhyolite Lamellae & Clots Define Foliation ---------- 41
Rhyolite Lamellae Define Foliation ---------- 42
Stop 8 area ---------- 43-48
Oblique Photomap View East ---------- 43
Oblique Photomap of Foliation Around Vent ---------- 44
Foliation on Northwest Syde of Vent ---------- 45
Foliation at Southwest Corner of Vent ---------- 46
Foliation at North Corner of Vent - Photomicrographs ---------- 47
Vent Breccia & Photomicrographs ---------- 48
Stop 9 area ---------- 49-52
Variable Foliation in Lava Flow ---------- 49
Scour Cuts Foliation - Photomicrographs of Lava ---------- 50
Conical Lava Plug Squirted into Breccia ---------- 51
Truncated Foliation ---------- 52
Stop 10 area ---------- 53-54
Foliated Rhyolite Grades into Shattered Rhyolite ---------- 53
Shattered Rhyolite ---------- 54
Stop 11 area ---------- 55-56
Curved Dike-Like Body in Shattered Rhyolite ---------- 55
Shattered Rhyolite & Slippage Surfaces ---------- 56
Stop 12 area ---------- 57-62
Variable Foliation in Lava Flow ---------- 57
Aligned Clots Define Foliation in Lava Flow ---------- 58
Joint Sets ---------- 59-60
Steeply Inclined Columnar Joints in Lava Flow ---------- 61
Angular Breccia ---------- 62
Stop 13 area ---------- 63-66
Steeply Dipping Foliation in Lava Flow ---------- 63
Clasts of Fine-Grained Rhyolite ---------- 64
Folded Flow Bands in Fine-Grained Clasts ---------- 65
Coarse-Grained Rhyolite Erodes Fine-Grained Clast & Rhyolite Clot -- 66
Stop 14 area ---------- 67-72
Fractured Clasts in Breccia ---------- 67
Tortoise-Shell Fractured Breccia & Photomicrographs ---------- 68
Traction-Carpet Breccia ---------- 69
Tortoise-Shell Fractures ---------- 70
Angular-Clast Traction-Carpet Breccia ---------- 71
Photomicrographs of Angular-Clast Traction-Carpet Breccia ---------- 72
Stop 15 - Aplite Breccia ---------- 73

Big Butte Volcanics

Abstract

The Big Butte volcanics consist of rhyolite that appears to overlie quartz latite. Both cover quartz monzonite and aplite of the Boulder batholith, and are probably part of the Eocene Lowland Creek volcanics. They take the form of dikes, a tuff dike, lava flows, ash flows, a welded tuff, a vent breccia, and a conduit filling. Except for the dike complex that underlies Tech's campus, all are composed of shattered crystals embedded in a finely crystalline to glassy groundmass. Microscopically, they look like explosively emplaced tuffs.

Acknowledgments

This is an attempt to decipher volcanics by a retired professor who taught structural geology, stratigraphy, and geomorphology. I am particularly indebted to Dick Berg for his suggestion that I should try to map Big Butte, for his help in the field interpretations, and for his great help in interpreting thin sections, an area where the author had accumulated 40 years of rust. Ed Deal was of enormous help in pointing out differences in rhyolites that, at first, looked much alike to me. His field identifications of welded tuff, ash flows, and lava flows were of critical importance. Mary MacLaughlin provided insights on fracture patterns in the rhyolites. Mark Sholes provided instruction in the use of the geology department's thin section equipment and in the use of a petrographic microscope and its camera for taking photomicrographs. Predictably, not everyone agrees on all aspects of the interpretation of the volcanics presented here, and differences of opinion are welcome. The interpretations are subject to revision, and I make no claim to divinely inspired insight.

Big Butte Volcanics

Age

Big Butte volcanics rest on quartz monzonite and aplite of the Boulder batholith. They do not share the hydrothermal alteration and mineralization of the quartz monzonite and aplite, and are probably Eocene in age, a part of the Lowland Creek volcanics.

Composition

Most are crystal-rich rhyolites that contain abundant quartz eyes, orthoclase, plagioclase, and biotite. They cover a volcanic rock that is much poorer in quartz, probably a quartz latite, that contains a few rounded quartz crystals scattered among orthoclase (sanidine), plagioclase, and biotite.

Types of volcanic deposits and textures

The rhyolites are interpreted to occur in a dike complex, a tuff dike, lava flows, ash flow tuffs, a welded tuff, a vent breccia, and as a conduit filling. The dike complex contains phenocrysts that are mostly intact crystals embedded in a finely crystalline groundmass. All the other deposits are made of fragmented crystals embedded in a finely crystalline or glassy groundmass.

The quartz latite is interpreted to occur in a dike and in lava flows. The dike contains a few rounded crystals of quartz scattered among mostly intact crystals of biotite, orthoclase (sanidine), and plagioclase embedded in a finely crystalline groundmass. The lava flows have a few rounded quartz fragments scattered among broken and intact phenocrysts of sanidine, plagioclase, and biotite embedded in a finely crystalline or glassy groundmass.

Dikes in the dike complex that underlies the Montana Tech campus typically show steeply dipping flow banding (foliation). Some developed prominent columnar joints as they cooled and contracted. Their phenocrysts are mostly intact crystals embedded in a finely crystalline matrix (Stop 2).

The tuff dike is only a few inches across, shows no foliation, and consists of rhyolite rich in small crystal fragments, some derived from Butte quartz monzonite or hydrothermal vein quartz (Stop 1).

Lava flows contain breccias and display variably oriented foliation that usually dips steeply (Stop 9). In places, they are shattered (Stop 10), and their lower parts are characterized by breccias and tortoise-shell fractures formed as the lava cooled and shrank (Stop 14). At mid levels, northwest striking joints form intersecting sets that dip steeply southwest and northeast (Stop 12). Steeply dipping columnar joints developed locally at Stop 12.

A possible ash flow tuff outcrops at Stop 3 and ash flow tuffs appear to underlie the colluvial-covered slopes on the south and southwest sides of Big Butte. They outcrop as nodular-weathering chunks of rhyolite containing irregular holes where less resistant fragments, perhaps pumice, have weathered out.

Welded tuff outcrops along the railroad at Park Street (Stop 1). It is rich in fragmented crystals embedded in a glassy to finely crystalline groundmass. Irregular to lens-shaped light streaks aligned to dip gently southwest are probably flattened and devitrified pumice fragments. A reddish volcanic rock, perhaps an andesite or a latite, is the most common xenolith. One piece of beige-to-red siltstone and a few pieces of Boulder batholith mafic clots also form xenoliths at this outcrop.

Vent breccia occurs on the southwestern flank of Big Butte (Stop 8). In the center of the structure, fine-grained rhyolite embeds reddish chunks of rhyolite and rounded pieces of aplite. The breccia is surrounded by foliated rhyolite that dips steeply inward toward the central breccia, forming a funnel-shaped structure. Both the breccia and the foliated rhyolite are rich in crystal fragments, indicating that the structure may have served as an outlet for an explosion in the underlying magma chamber.

The top of Big Butte is interpreted as a conduit filling (Stop 7). Its rhyolite is rich in crystal fragments embedded in a glassy to finely crystalline groundmass. Microscopically, it is identical to the welded tuff at the Park Street railroad cut. For the most part, its foliation strikes northeastward, is vertical, and is defined by rhyolite lamellae, ribs, and clots that are slightly more resistant to weathering. Biotite flakes also tend to parallel the foliation. All these structures are interpreted to have formed as magma rose through the conduit to emerge as ash flows or lava flows.

Interpretation problems

Breccias near the base, variable foliation, locally shattered rhyolite, and tortoise-shell fracturing are structures likely to develop in lava flows, but all of the ryholites, except for the dike complex that underlies the Tech campus, are made of crystal fragments. Microscopically, they look like explosively emplaced tuffs.

Hypotheses:

Could it be that ground water entered the magma chamber to produce explosions that fragmented the crystal rich magma before it rose through the newly created vent to emerge first as ash flows and then as lava flows?

Is it possible that the magma emerged as ash flows that ponded and then flowed to form lava flow type structures? If it did, it had to cover a spring or pond as an ash flow at Stop 10, then flow to develop flow banding, and then shatter as steam from the spring or pond exploded through it.

Is there a hybrid between a lava flow and an ash flow that is fluid enough to flow like lava, while it still contains enough explosive gas to shatter its crystals as it flows?

The shattered crystals in the tuff dike, the conduit, and the funnel vent indicate that magma chamber explosions accompanied eruptions, but there is still a choice as to how the expelled magma traveled over the ground.

Viewing Stereo Images

Many of the pictures in the guidebook are presented as stereo pairs. To see the image in three dimensions, you need to look at the right image with the right eye and the left image with the left eye. To do this, pick out some prominent feature in the pictures and stare beyond the pictures. The two prominent features, one from each picture, should float together in the center. This center image will be in three dimensions. At first it may not be in focus. You are accustomed to associate convergence of your eyes with focus. If you continue to stare at the center image, your mind will ultimately relent and focus on the center image while your gaze remains parallel, each eye looking at its respective image.

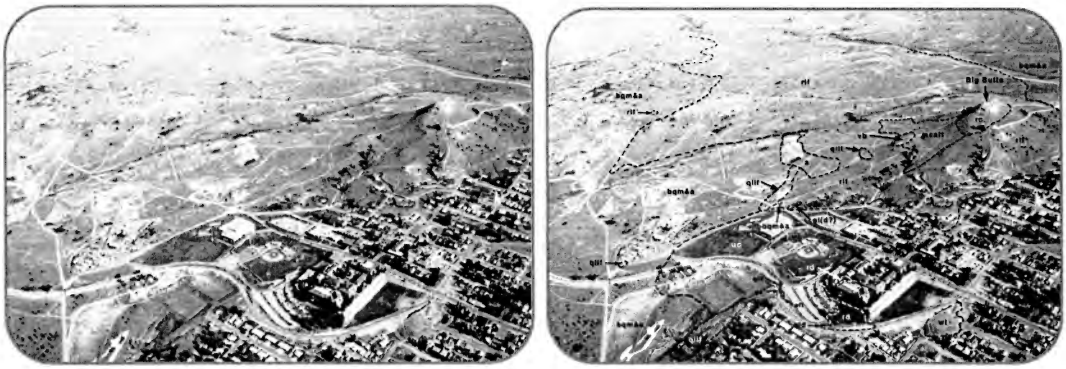
A simple exercise may help prepare you for this unaccustomed way of viewing. With your hands at arm's length in front of your eyes, touch your two index fingers together as you look beyond them. You should see a sausage image between your two index fingers. Your eyes are parallel, the right one looking at the right finger, the left one at the left finger. The two images have floated apart, the right one to the left and the left one to the right to form the sausage. The feeling in your eyes is the one you should try to imitate when looking at the stereo images. Some will master the technique instantly. It will take longer for others. If you don't succeed at first, keep trying at odd times. Try sometime when you are really tired and tend to see double images anyway when you stare at objects. If I could learn to do it, anyone with two good eyes can. I worked at it off and on for over two years before I suddenly learned the knack.

Your eyes are just a few inches apart. With that small separation, you can see in three dimensions for about 1100 feet. Some of these images were taken from a small airplane flying at a speed of about 100 mph. The interval between the two images varied from one second to several seconds, giving an effective eye base of between 100 and several hundred feet. With this eyebase, you can see in three dimensions for miles. These pictures produce spectacular three dimensional views not easily obtainable in any other way.

The photomicrographs are most often presented as two images, one taken with plane polarized light, the other with crossed polarizers. They are not stereo images. The thin sections are only about .03mm in thickness. They are arranged at opposite edges of the page so you will not confuse them with stereo pairs.

Interpretation of Big Butte volcanics

Oblique Photomap

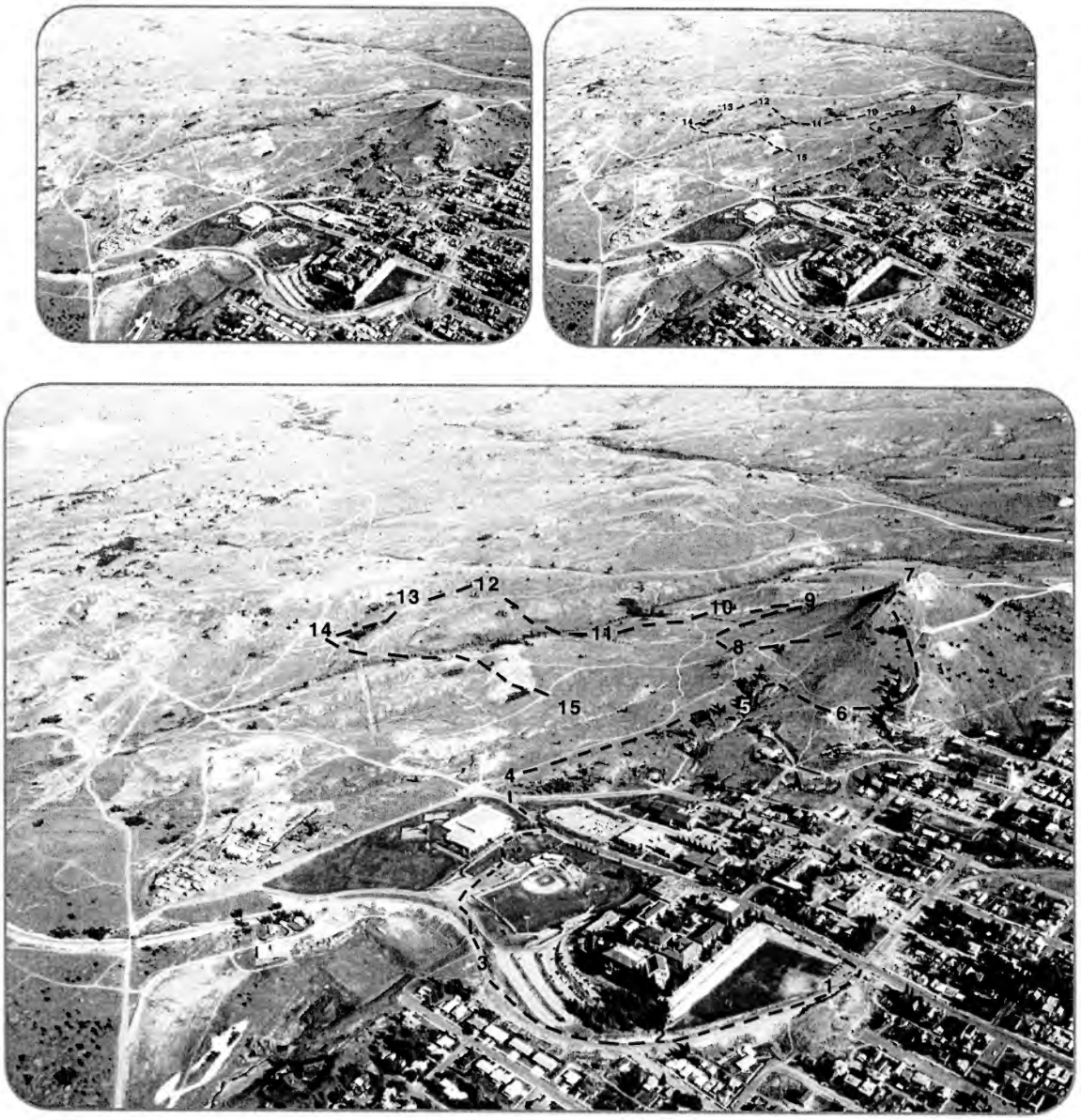


You are looking toward the northwest at Big Butte and its volcanics

a = aplite aft = ash flow tuff bqm&a = butte quartz monzonite and aplite
ga = granoaplite mcaft = mostly covered ash flow tuff qld = quartz latite dike
qllf = quartz latite lava flow rc = rhyolite conduit rd = rhyolite dike
rlf = rhyolite lava flow uc = urban cover vb = vent breccia wt = welded tuff

Route of Big Butte volcanics field trip

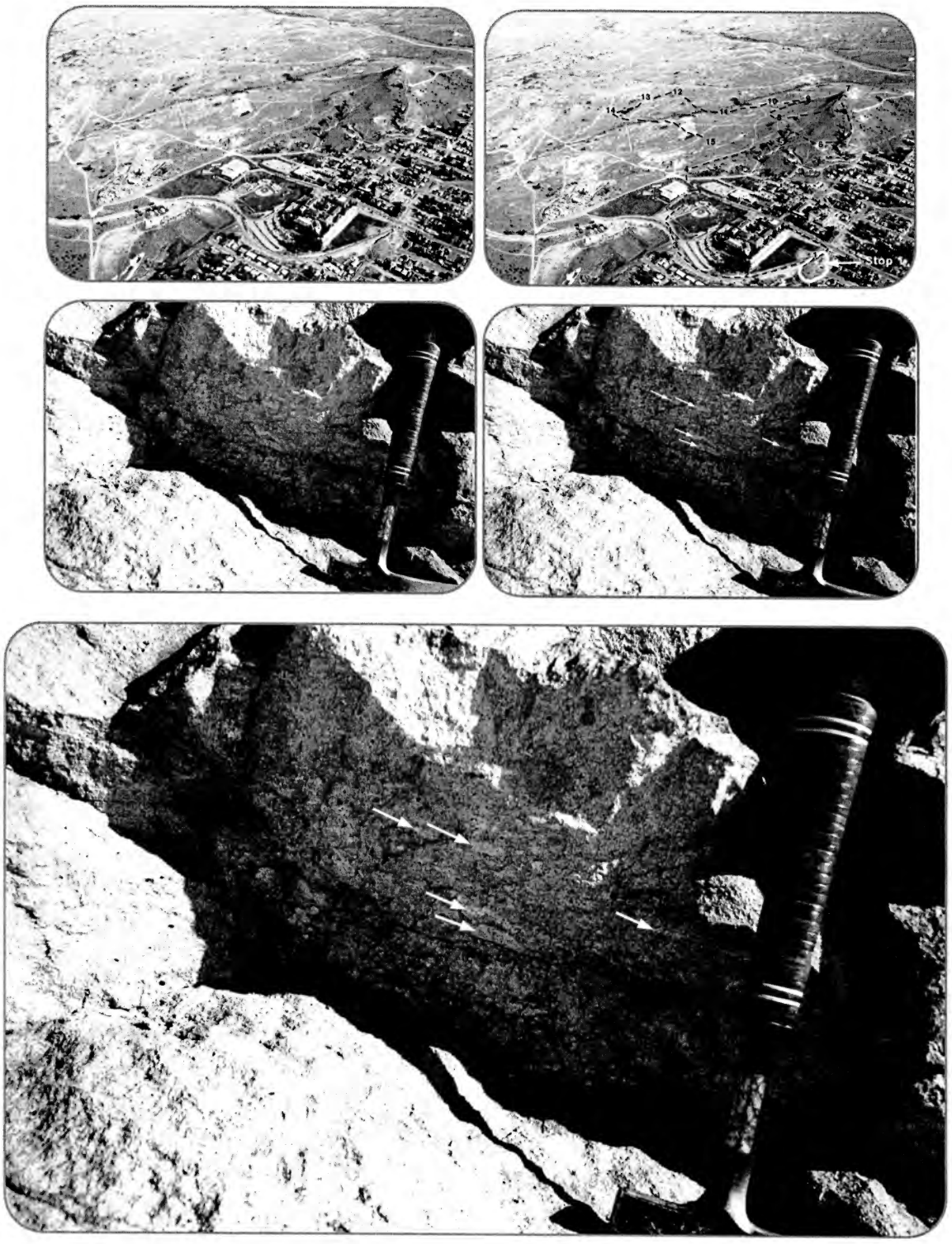
Trip Route



Route of walking field trip to observe the rhyolites of Big Butte. Outcrops of particular interest are numbered, and both text and pictures in the guidebook are keyed to them.

Big Butte volcanics Stop 1

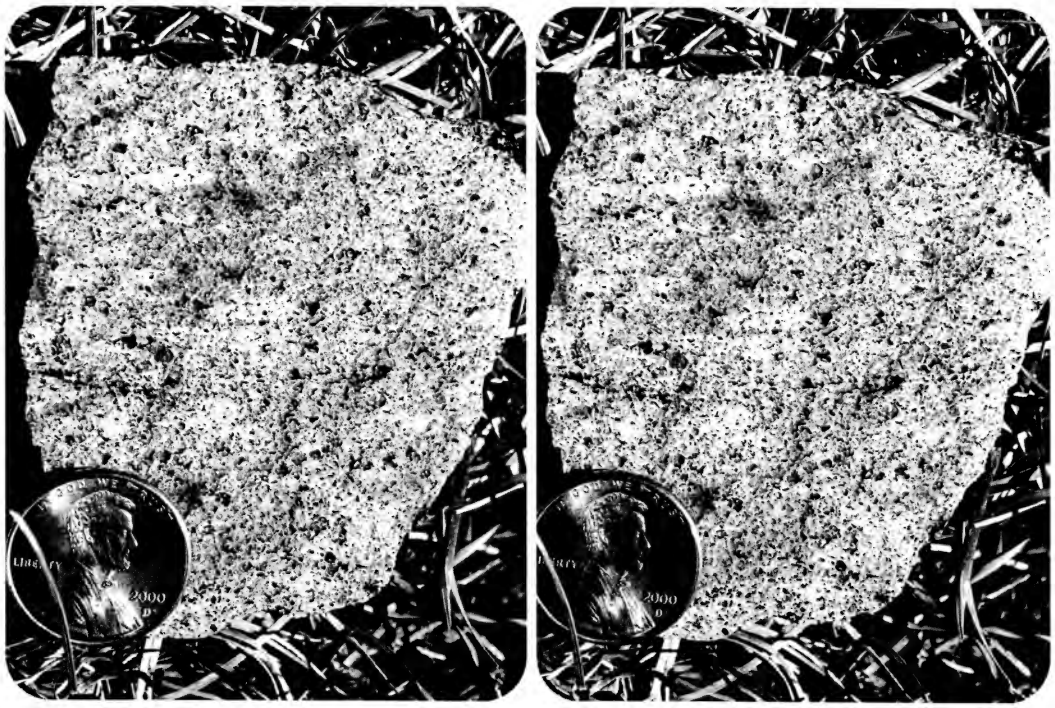
Eutaxitic Texture



Arrows point to a few of the light streaks that are probably flattened and devitrified pumice fragments defining a eutaxitic texture that strikes northwest and dips about 15 degrees southwest.

Big Butte volcanics Stop 1

Welded Tuff

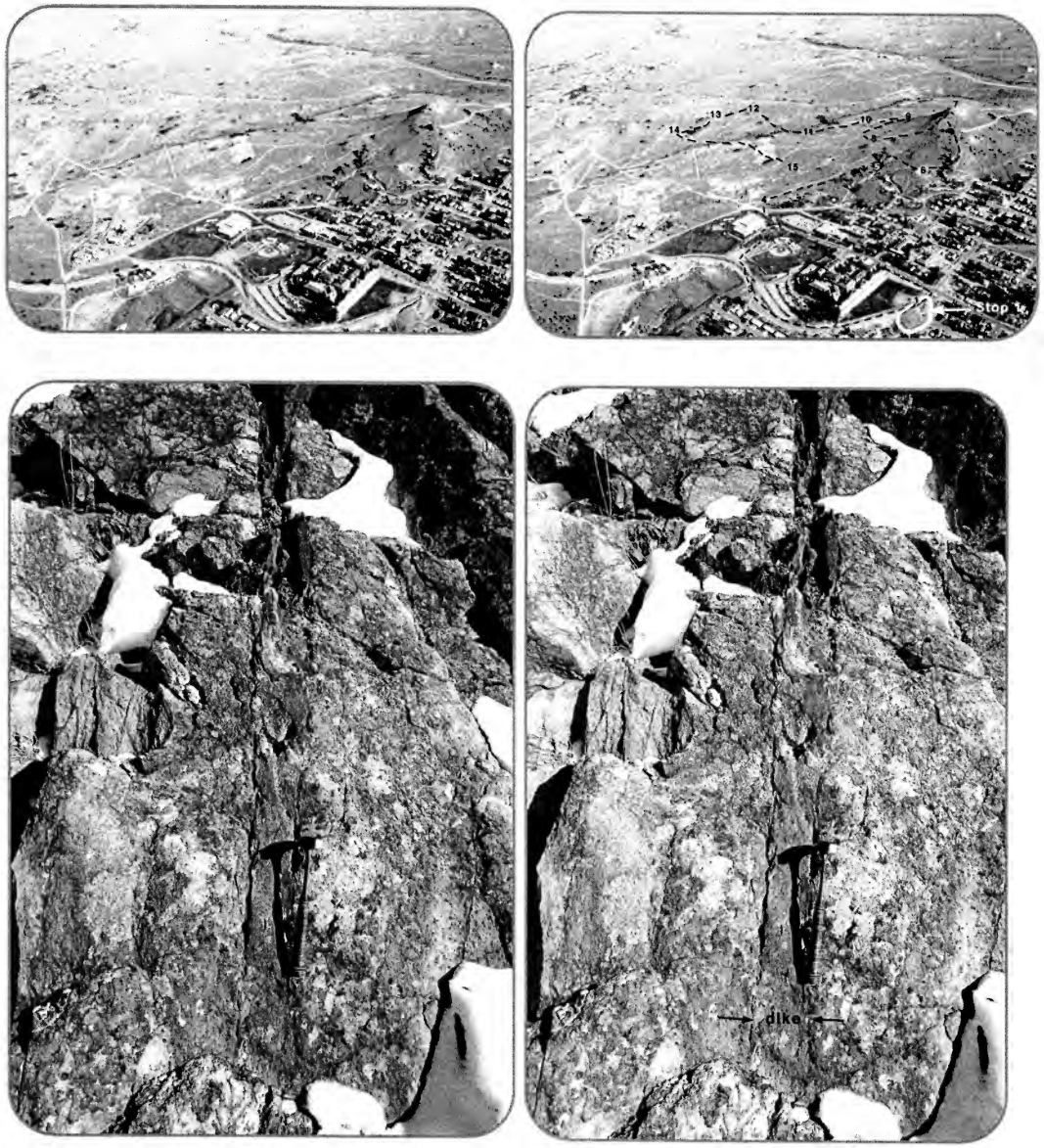


The light streaks in the slabbed specimen shown above are probably flattened and devitrified pumice fragments in a welded tuff.

Both photomicrographs of a thin section from the outcrop at Stop 1 are about 50x magnification. The left one used plane polarized light; the right one used crossed polarizers. The thin sections show crystal fragments of feldspar, quartz, and biotite embedded in an isotropic glassy to finely crystalline matrix. The quartz crystals tend to be rounded and embayed.

Big Butte volcanics Stop 1

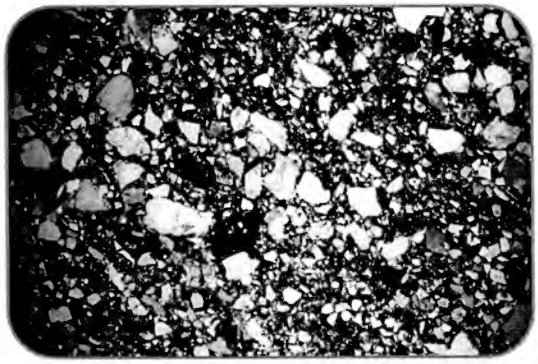
Tuff Dike

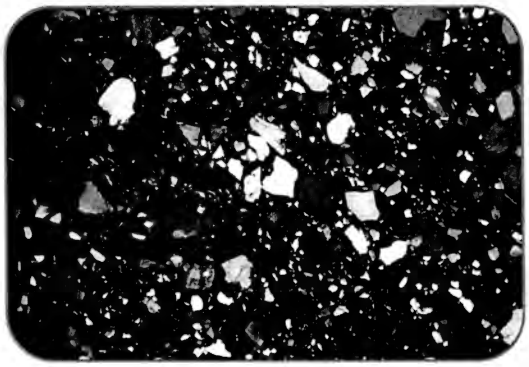


The hammer is stuck into the edge of a tuff dike that cuts through the welded tuff. Crystal fragments in the tuff dike are smaller than those in the welded tuff.

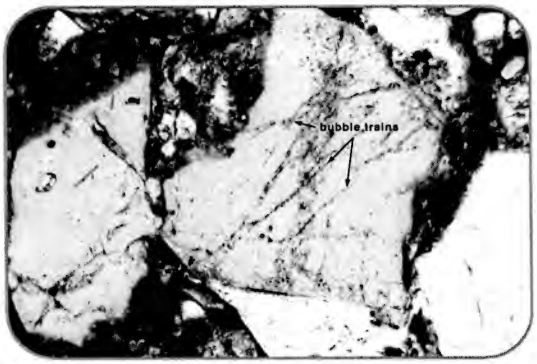
Big Butte volcanics Stop 1

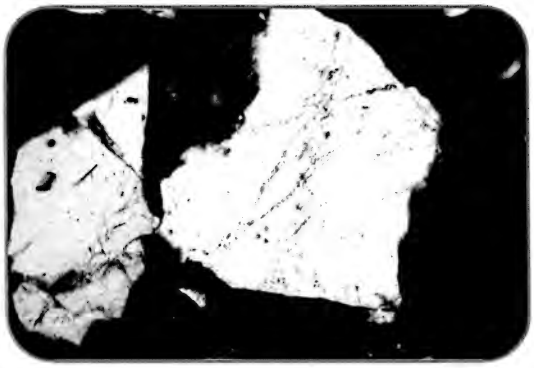
Photomicrographs of Tuff Dike





Photomicrographs above are of a thin section from the tuff dike shown on the facing page. Magnification is approximately 50x. Left photo is with plane polarized light; right photo is with crossed polarizers. The fine crystal fragments may have been blown apart by a magma chamber explosion that hurled them along a fracture through Butte quartz monzonite and the welded tuff to explode out into the atmosphere.

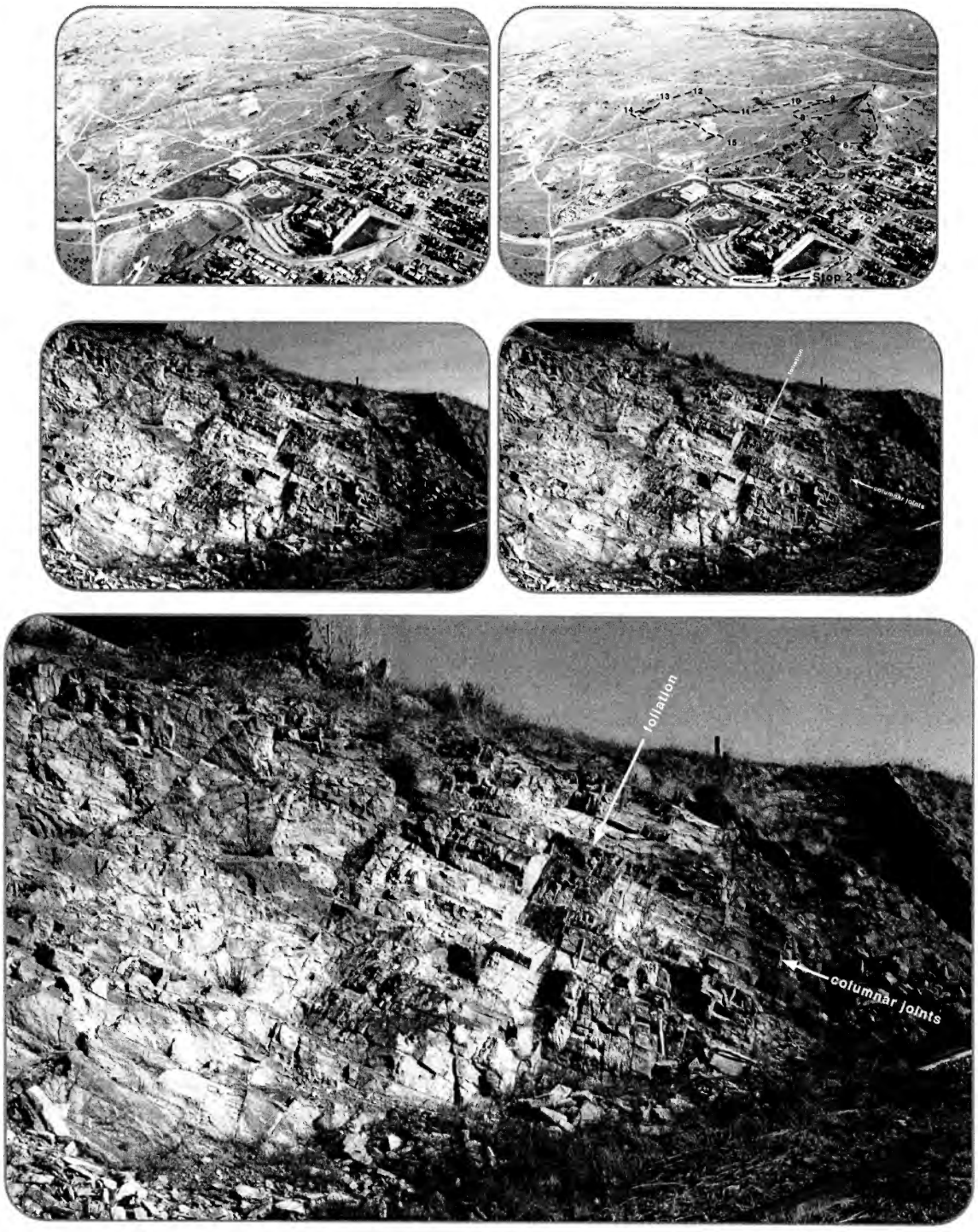




These photomicrographs are of the quartz fragment in the centers of the pictures directly above them. Magnification is about 400x. Left photo is with plane polarized light; right photo is with crossed polarizers. Both photos show trains of bubbles along fractures in the quartz, a characteristic of plutonic and hydrothermal quartz. No quartz crystals containing trains of bubbles have been found in the rhyolites of the Big Butte area, but numerous quartz grains in the tuff dike contain them. The quartz grains probably were picked up as the exploding tuff followed fractures across Butte quartz monzonite and hydrothermal quartz veins.

Big Butte volcanics Stop 2

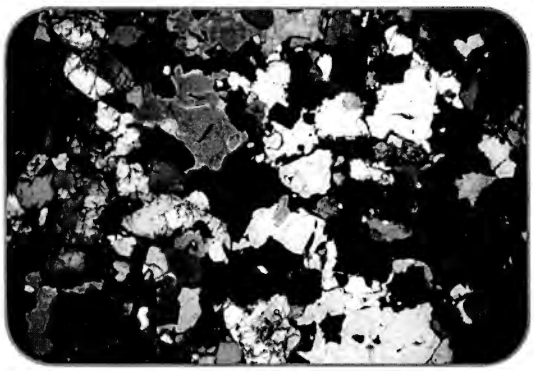
Inclined Columnar Joints

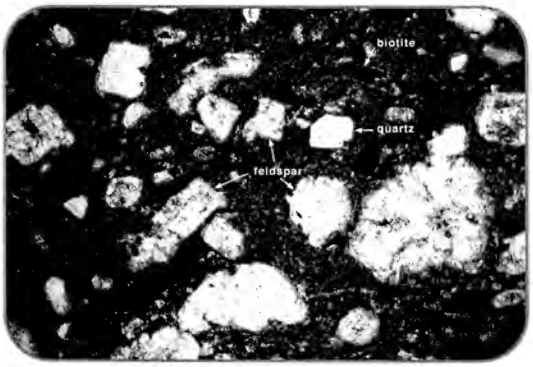


Columnar joints propagated from a hidden boundary surface on the right into this dike complex, fading out upward and toward the left. Flow banding (foliation) is approximately perpendicular to the columnar joints.

Big Butte volcanics Stop 2

Photomicrographs Columnar-Jointed Dike





Photomicrographs of thin sections: magnification approximately 50x

The photomicrograph above is of a specimen collected where the columnar joints fade into the dike rock to the left in the picture on the facing page. The polarizers are crossed to show the interlocking crystals of feldspar, quartz, and biotite. Atypically, no groundmass is apparent in this thin section.

The photomicrograph above is of a specimen collected from the middle of the columnar-jointed dike shown on the facing page. Polarizers are not crossed. Phenocrysts of feldspar, quartz, and biotite are mostly intact crystals embedded in a finely crystalline matrix.

Big Butte volcanics Stop 2

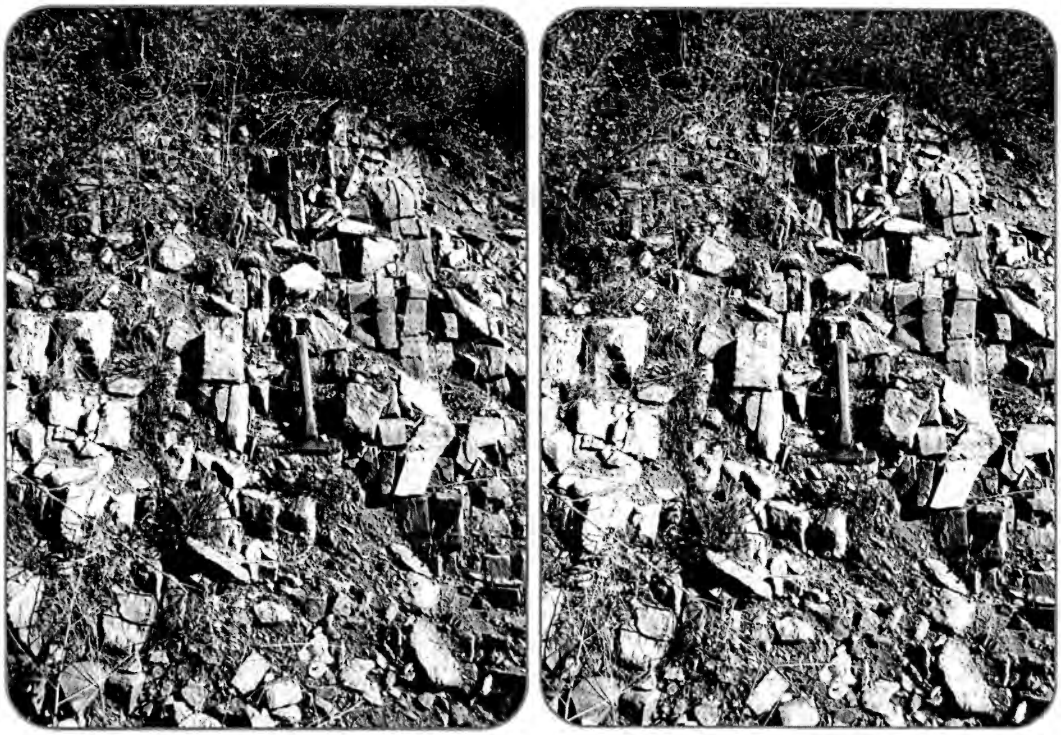
Columnar Jointed Dike

A columnar-jointed rhyolite dike intruded approximately parallel to the foliation of the dike complex that underlies Montana Tech's campus. The phenocrysts in the rhyolite of the columnar-jointed dike and in the adjacent dike complex are mostly intact crystals embedded in a finely crystalline groundmass.

Big Butte volcanics Stop 2

Dike Foliation

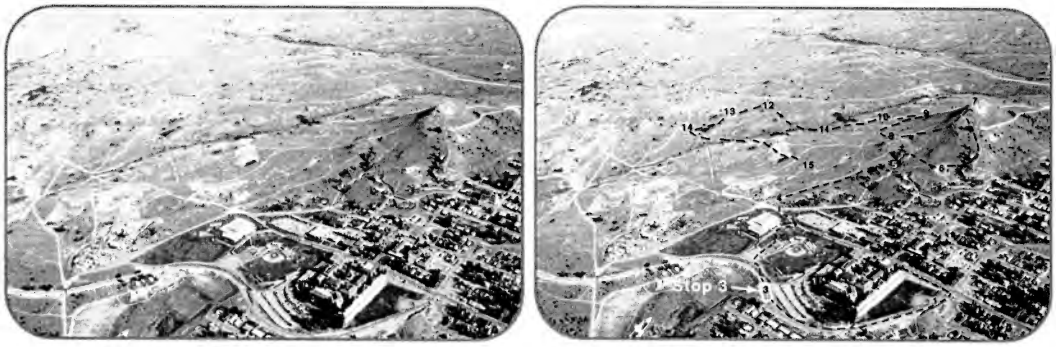
Foliation within the columnar-jointed dike shown on the facing page swirls a bit, but remains nearly perpendicular to the columnar joints.

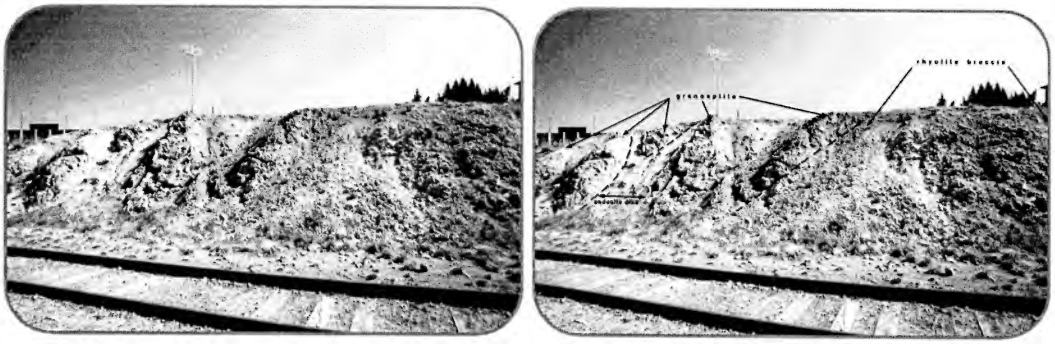


Foliation is vertical in a quartz latite dike at the western end of Stop 2. Its phenocrysts are mostly intact crystals embedded in a finely crystalline groundmass.

Big Butte volcanics Stop 3

Rhyolite Breccia





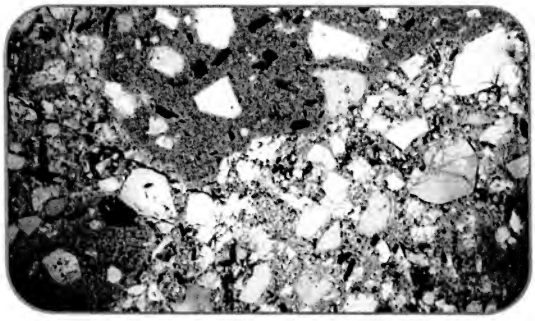
Rubbly weathering rhyolite breccia contains xenoliths of quartz monzonite and granoaplite as well as abundant white-weathering fragments of rhyolite, some of which weather out, leaving irregular holes. An ash flow, a pyroclastic flow, or a cold mudflow could have deposited the breccia. The contact of the rhyolite breccia with the gra-

Big Butte volcanics Stop 3

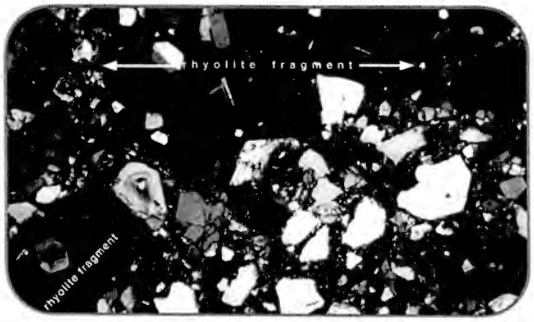
Rhyolite Breccia

noaplite dips steeply westward as if the breccia filled in under an overhang. That seems unlikely. Perhaps a landslide changed the original orientation of the contact. An andesite dike that branches upward intruded the granoaplite.

Arrows point to a few of the rhyolite rock fragments contained in a matrix of broken feldspar, biotite, and quartz crystals, as shown in the photomicrographs below.



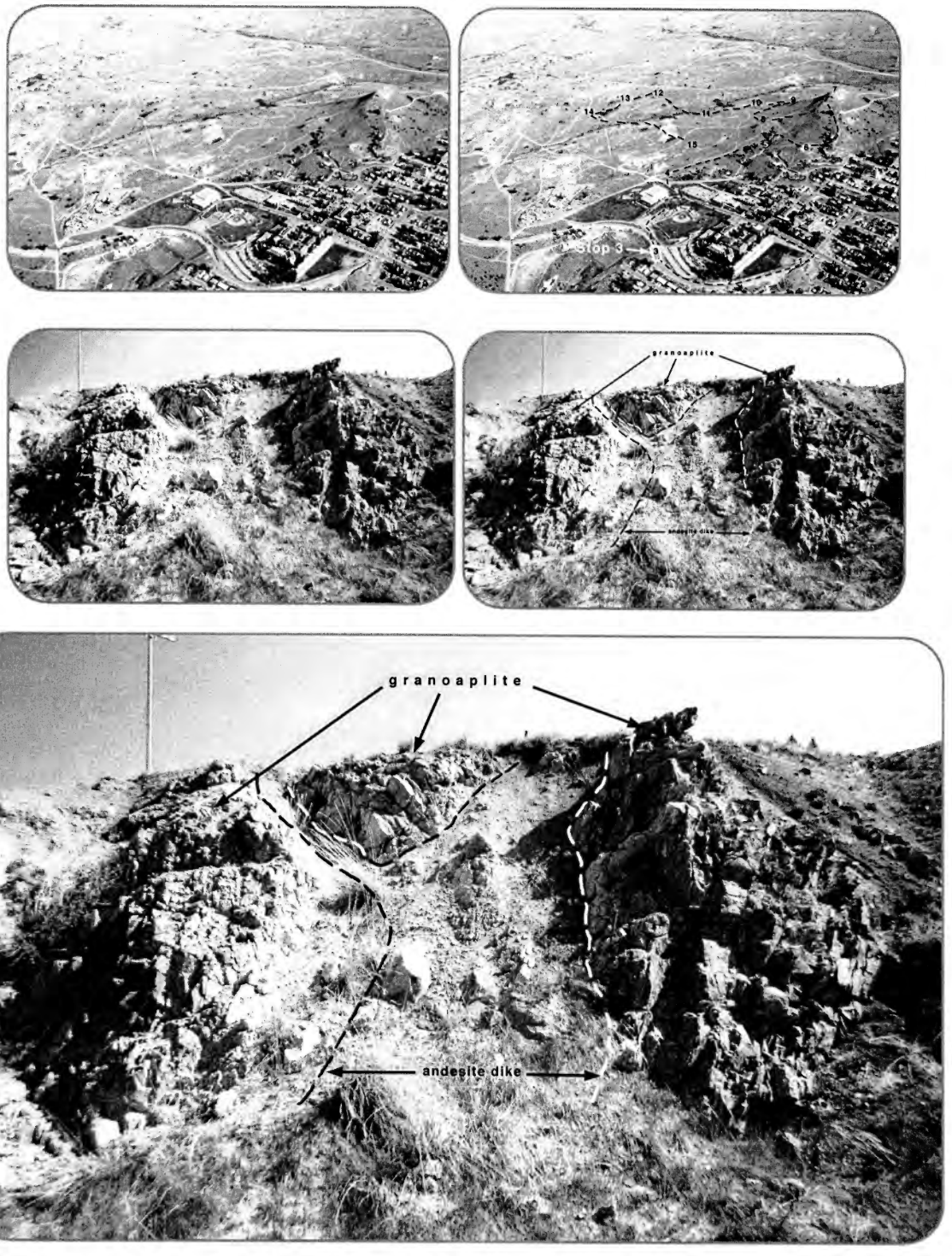
Plane polarized, 50x magnification



Crossed polarizers, 50x magnification

Big Butte volcanics Stop 3

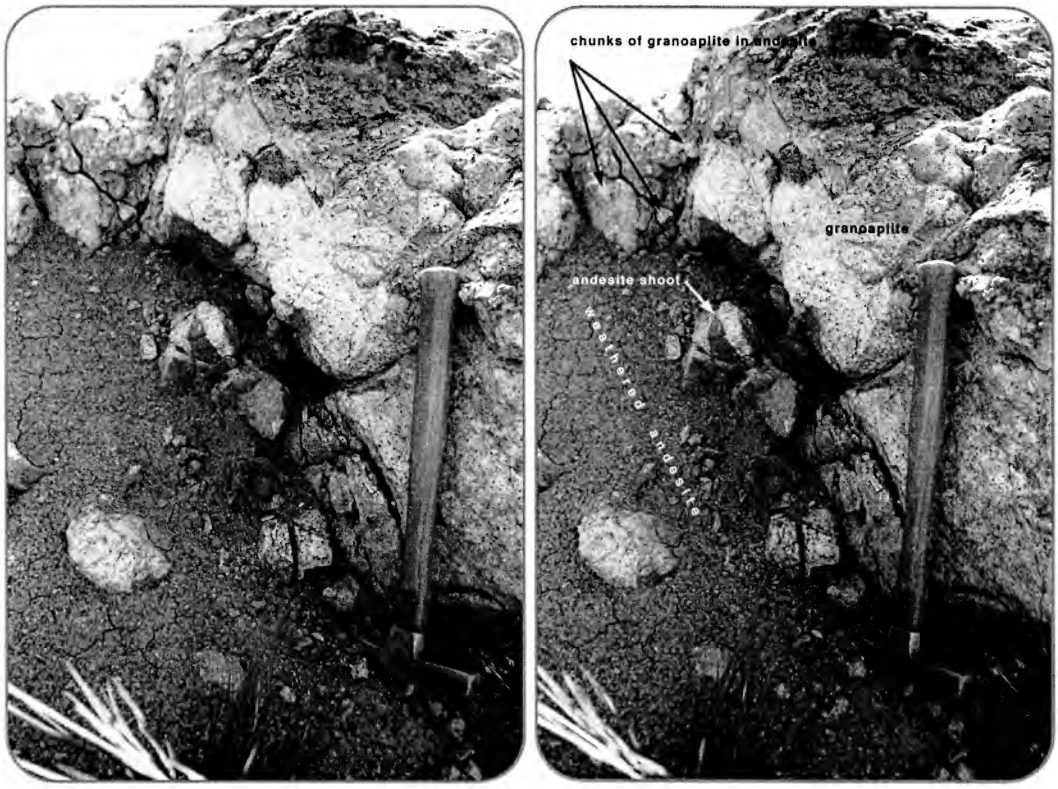
Andesite Dike Cuts Granoaplite



A branching andesite dike intrudes granoaplite.

Big Butte volcanics Stop 3

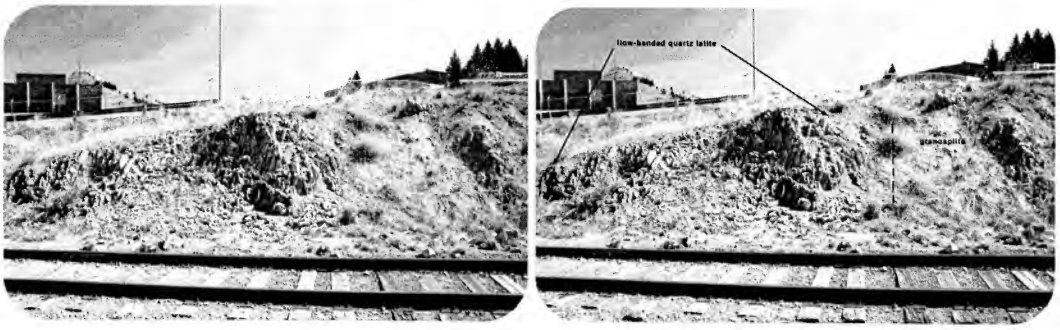
Andesite Dike Cuts Granoaplite



Shoots of andesite squirted into granoaplite, and chunks of granoaplite sank into the molten andesite as the andseite forced its way through the granoaplite. This picture is a close view of the top right part of the andesite dike shown in the picture on the facing page.

Big Butte volcanics Stop 3

Quartz Latite Lava Flow

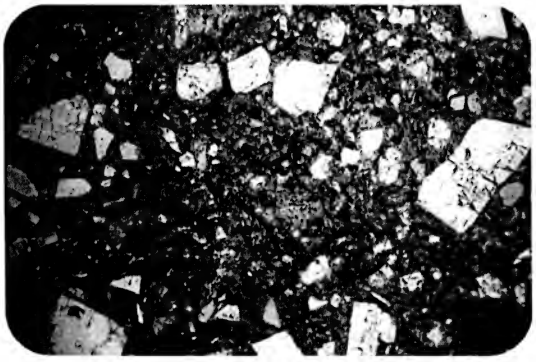


The contact is approximate in the covered interval between a flow-banded quartz latite lava flow and granoaplite at the western end of the outcrop at Stop 3.

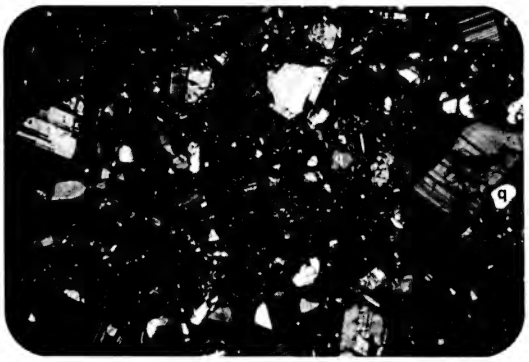
Big Butte volcanics Stop 3

Foilation & Photomicrographs Quartz Latite

Arrows point along the flow banding (foliation) in the quartz latite lava flow.



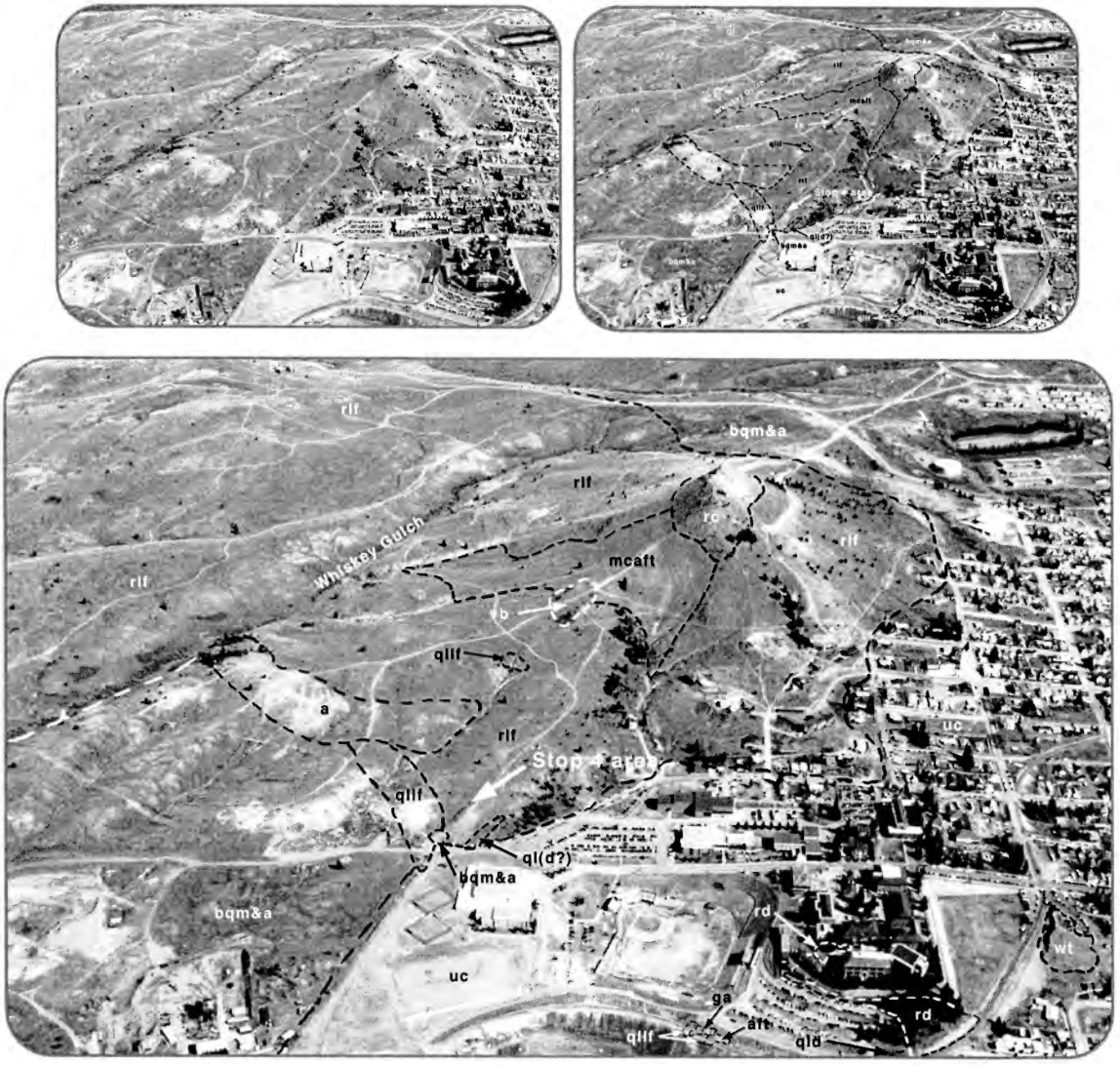
The broken crystals are mostly feldspar embedded in a glassy to finely crystalline matrix in the flow-banded quartz latite shown above. Plane polarized light, magnification approximately 50x.



The glassy to finely crystalline matrix remains dark under crossed polarizers. Two small fragments of quartz are labelled "q". Magnification is approxiamtely 50x.

Big Butte volcanics Stop 4

Oblique Photomap



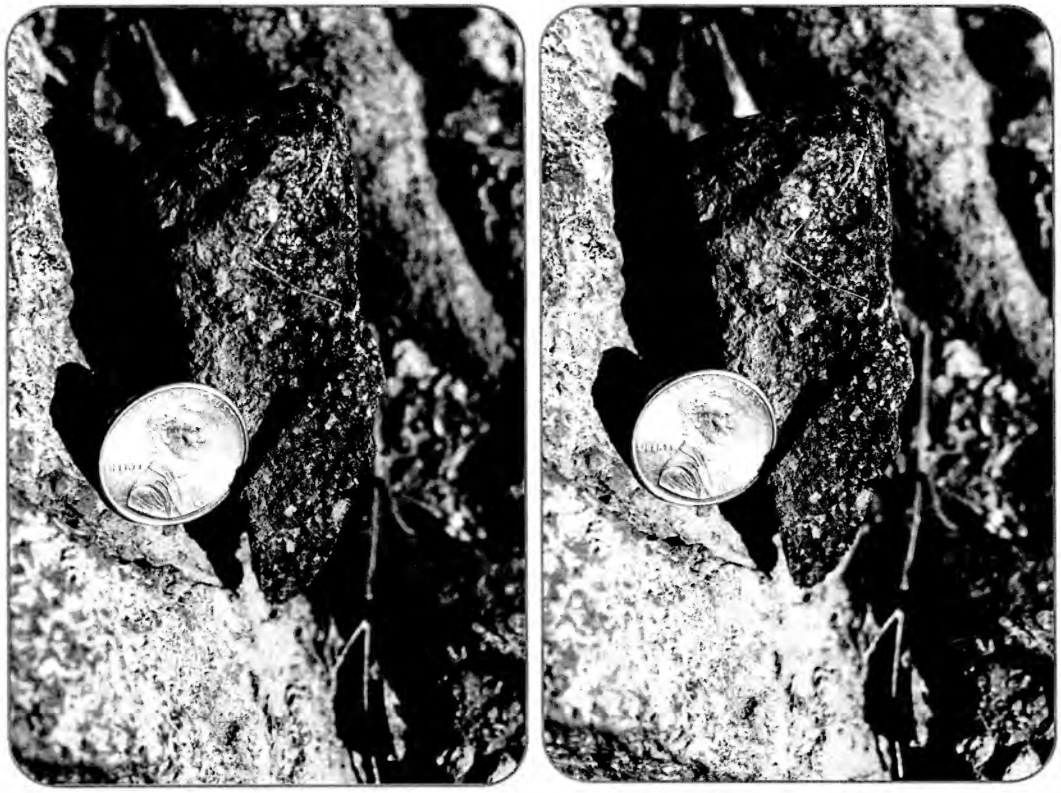
You are looking northward at the volcanics around Stop 4.

a = aplite aft = ash flow tuff bqm&a = butte quartz monzonite and aplite
ga = granoaplite mcaft = mostly covered ash flow tuff qld = quartz latite dike
qllf = quartz latite lava flow rc = rhyolite conduit rd = rhyolite dike
rlf = rhyolite lava flow uc = urban cover vb = vent breccia wt = welded tuff

At Stop 4 rhyolite lava is topographically higher than the quartz latite lava flow and may overlie it. Rhyolite separates the quartz latite lava flow from a narrow outcrop of quartz latite to the east that may be a dike, ql(d?) It shows nearly vertical flow banding and its eastern margin is lined by finely crystalline quartz latite. A few pieces of vitrophyre occur in the rhyolite just east of the head of the white arrow that points to the Stop 4 area.

Big Butte volcanics Stop 4

Obsidian - Photomicrographs



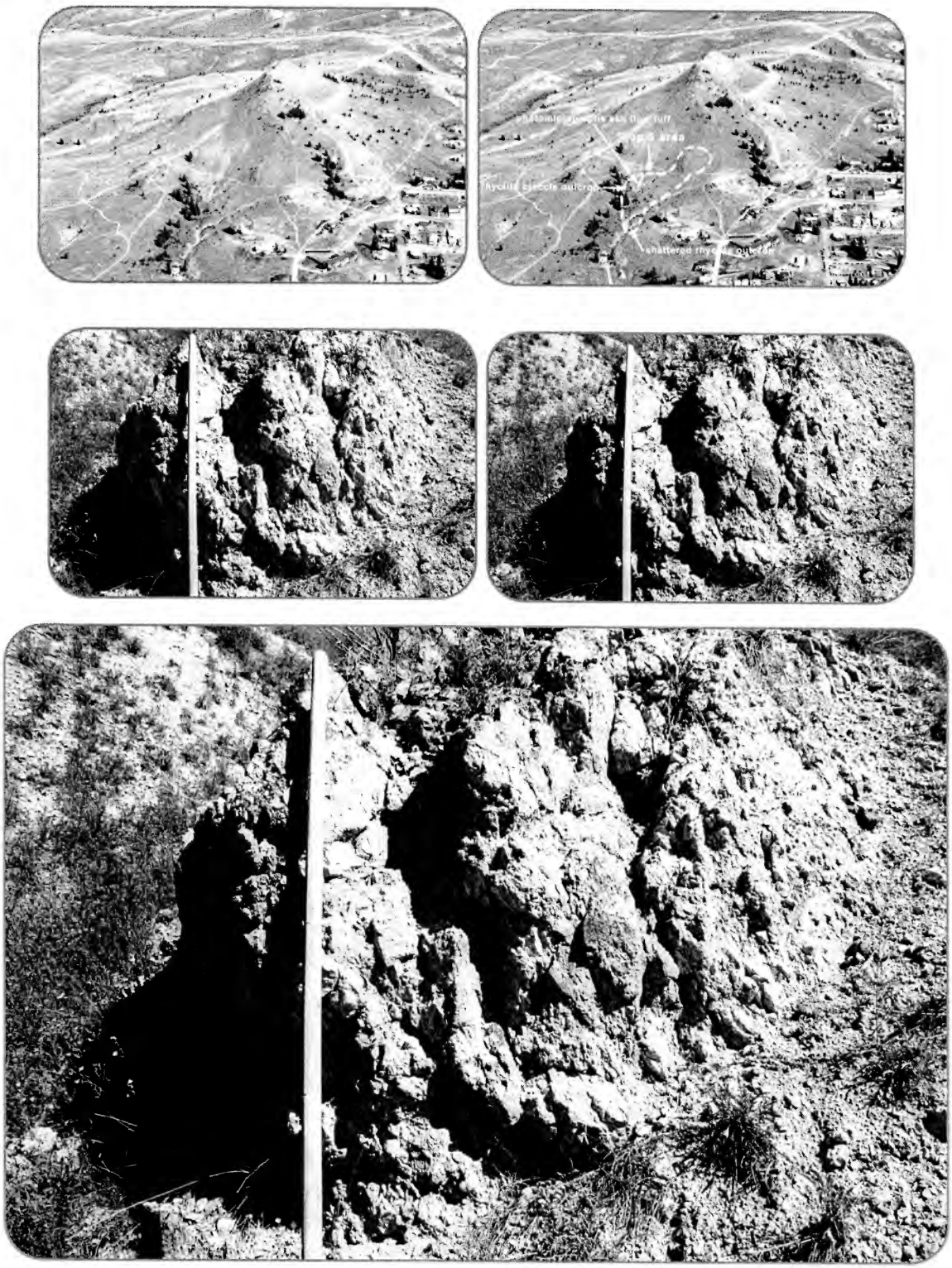
The penny rests against a weathered surface and a freshly broken piece of obsidian. Several pieces of obsidian containing crystals of feldspar and biotite occur scattered over a few square meter area on the rhyolite lava flow near the western end of Park Street.

Vitrophyre

The left photomicrograph was taken with plane polarized light; the right one was taken with crossed polarizers. Magnification is approximately 50x. The dark crystals in the left photomicrograph are biotite. The light crystals are feldspars. Both are embedded in obsidian. Quartz is absent. It is possible that the obsidian froze in an earlier quartz-deficient lava and was later picked up by the quartz-rich rhyolite lava that carried it to this location. No other obsidian-rich vitrophyre has been found on Big Butte. It is also possible that chunks of obsidian-rich vitrophyre collected elsewhere were dropped by vagrant rock collectors at this spot.

Big Butte volcanics Stop 5

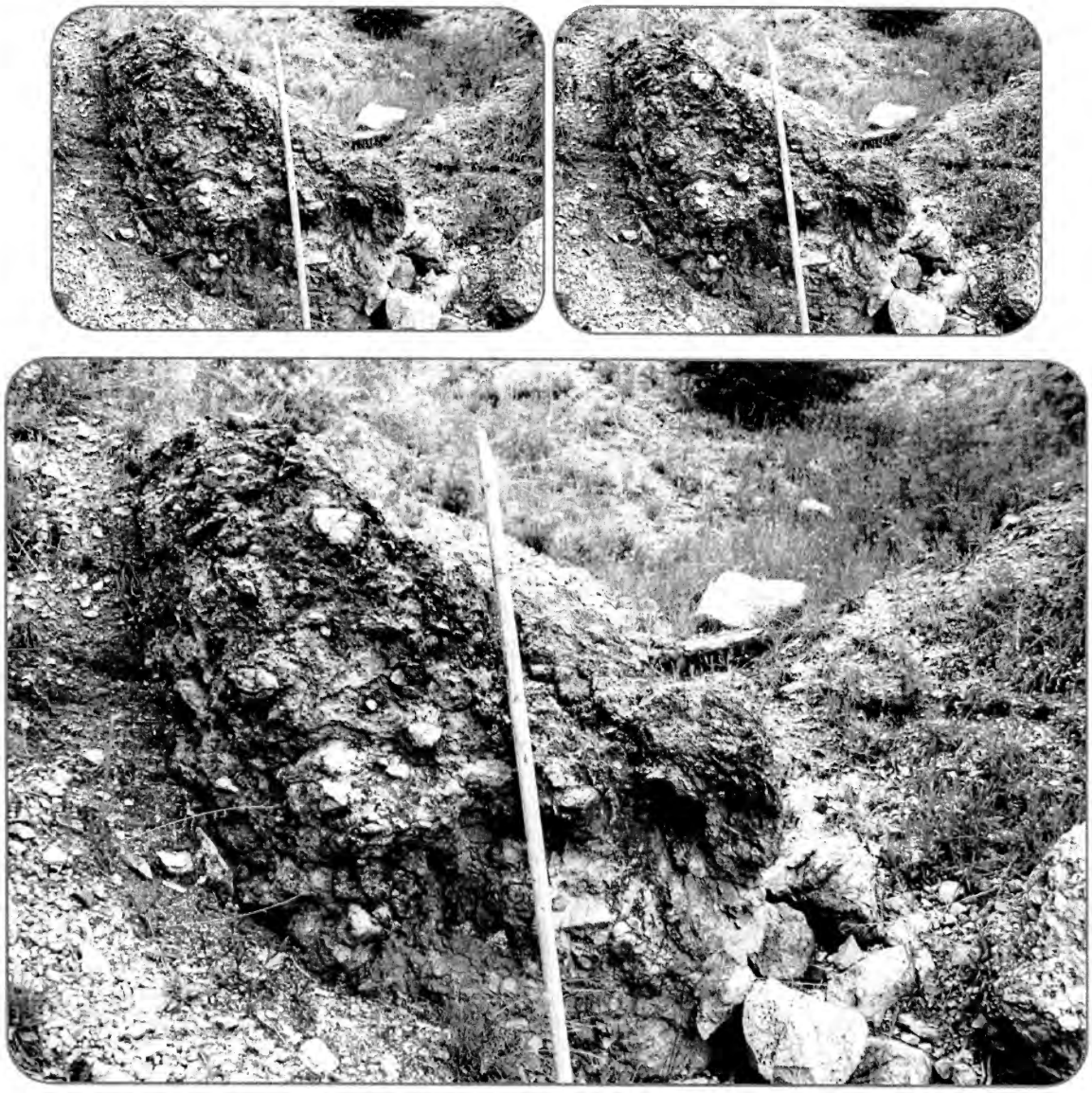
Shattered Rhyolite



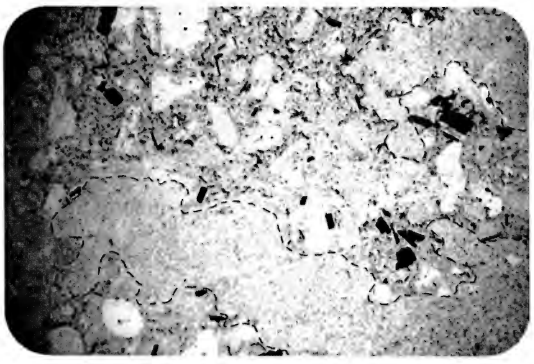
This outcrop is interpreted as shattered rhyolite of a lava flow. The flow may have passed over a wet area that generated steam for explosions that shattered the rhyolite.

Big Butte volcanics Stop 5

Rhyolite Breccia



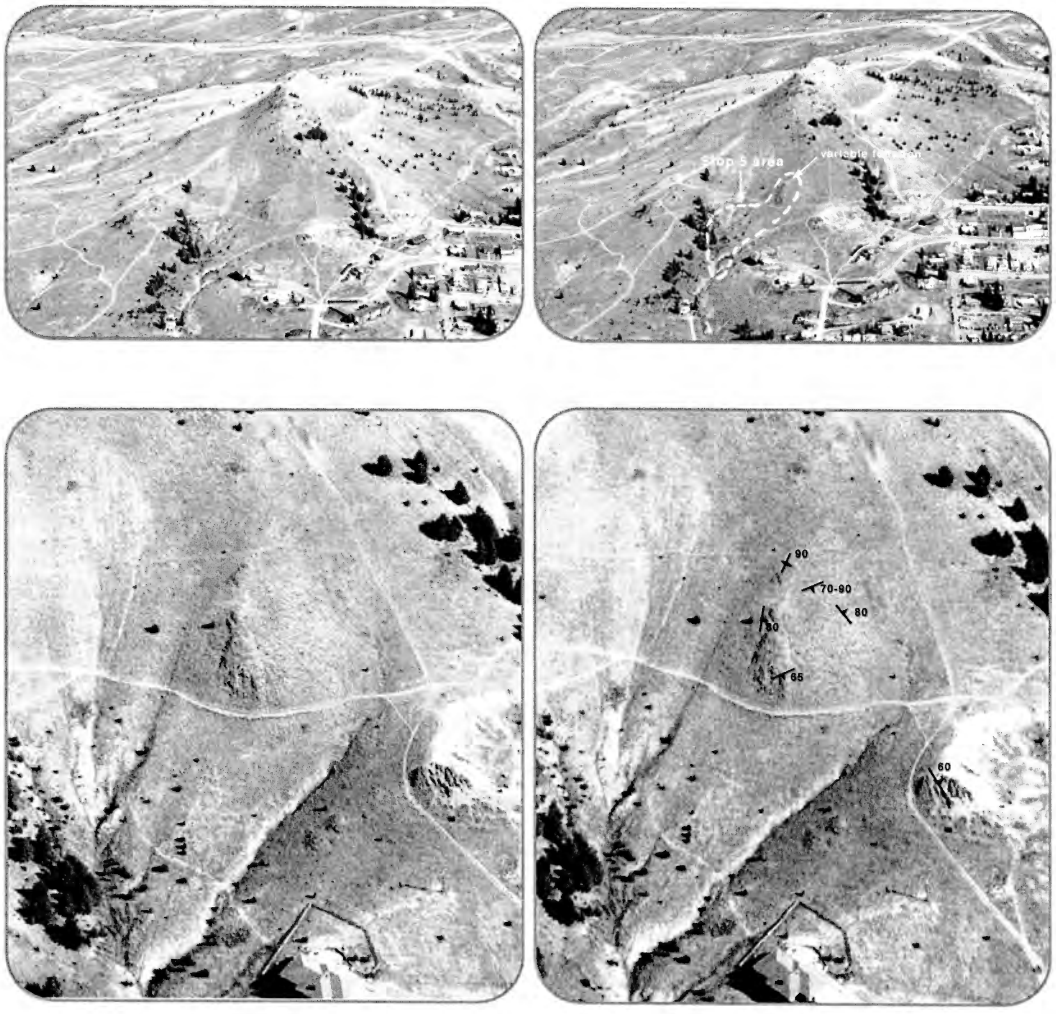
This outcrop is interpreted as a traction carpet breccia at the base of a rhyolite flow.



Photomicrograph in plane polarized light at a magnification of about 50x. The dashed lines outline finely crystalline areas that could be silicified pumice. The deposit occurs adjacent to and to the right of the breccia shown above. It is interpreted to be an of ash flow tuff that underlies the breccia. Most of the ash flow tuff is too friable to grind into an acceptable thin section, but this coherent piece of tuff may have been silicified by vapors rising locally through the ash flow.

Big Butte volcanics Stop 5

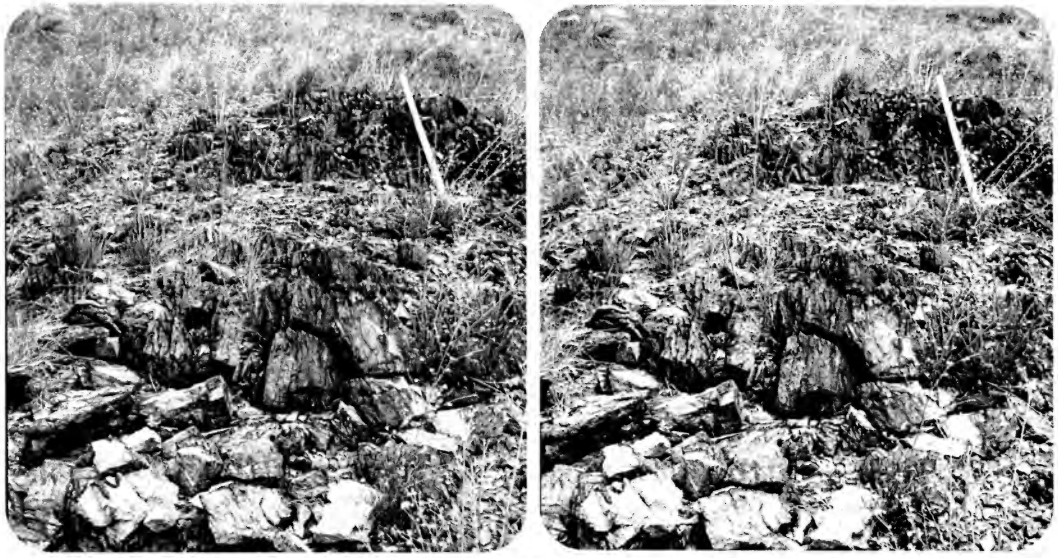
Variable Foliation



This bulge on the side of Big Butte is interpreted to be part of a rhyolite lava flow. Characteristically, it shows steeply dipping foliation in variable orientations.

Big Butte volcanics Stop 5

Variable Foliation

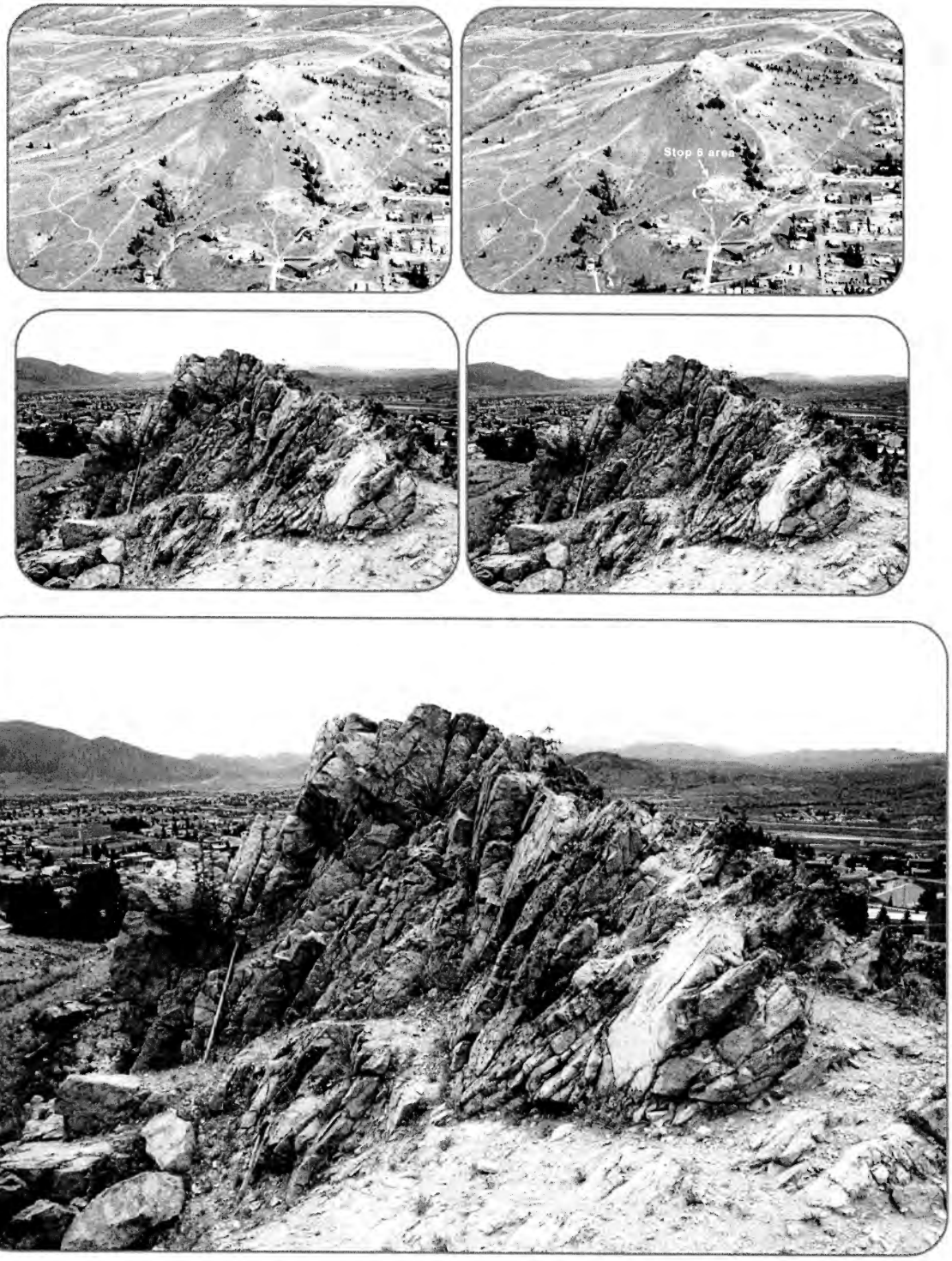


Foliation shown at the top of the outcrop on the facing page - N 45 E, 90

Foliation - N 70 E, 65 SE

Big Butte volcanics Stop 6

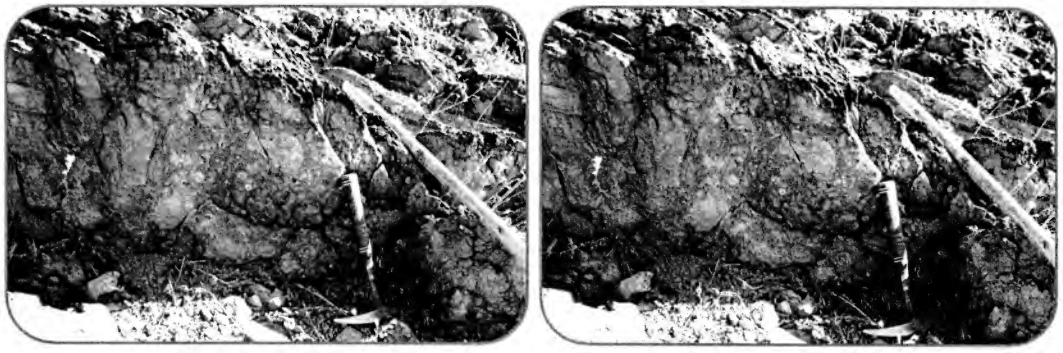
Steeply Dipping Foliation



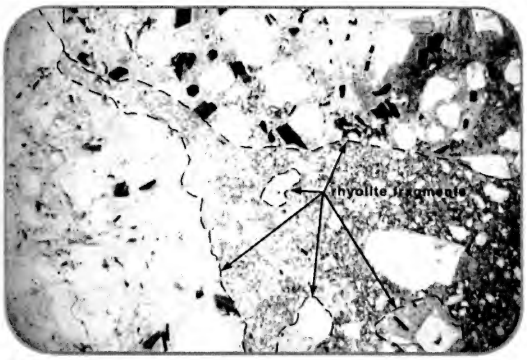
You are looking southward at the steeply dipping foliation of the rhyolite on the western side of the quarry below Big Butte. The foliation strikes from about N-S to N 15 W and dips from about 50 degrees to 70 degrees eastward.

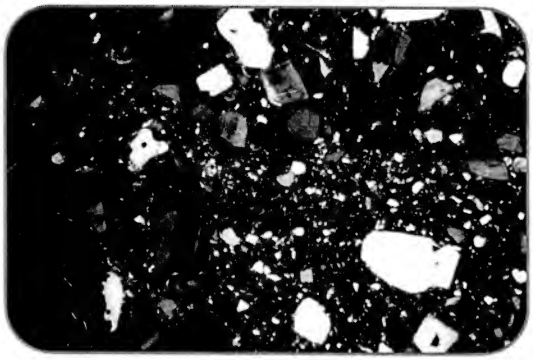
Big Butte volcanics Stop 6

Rhyolite Breccia - Photomicrographs



Rounded and broken rhyolite fragments are exposed on a foliation surface that dips steeply eastward, away from you.

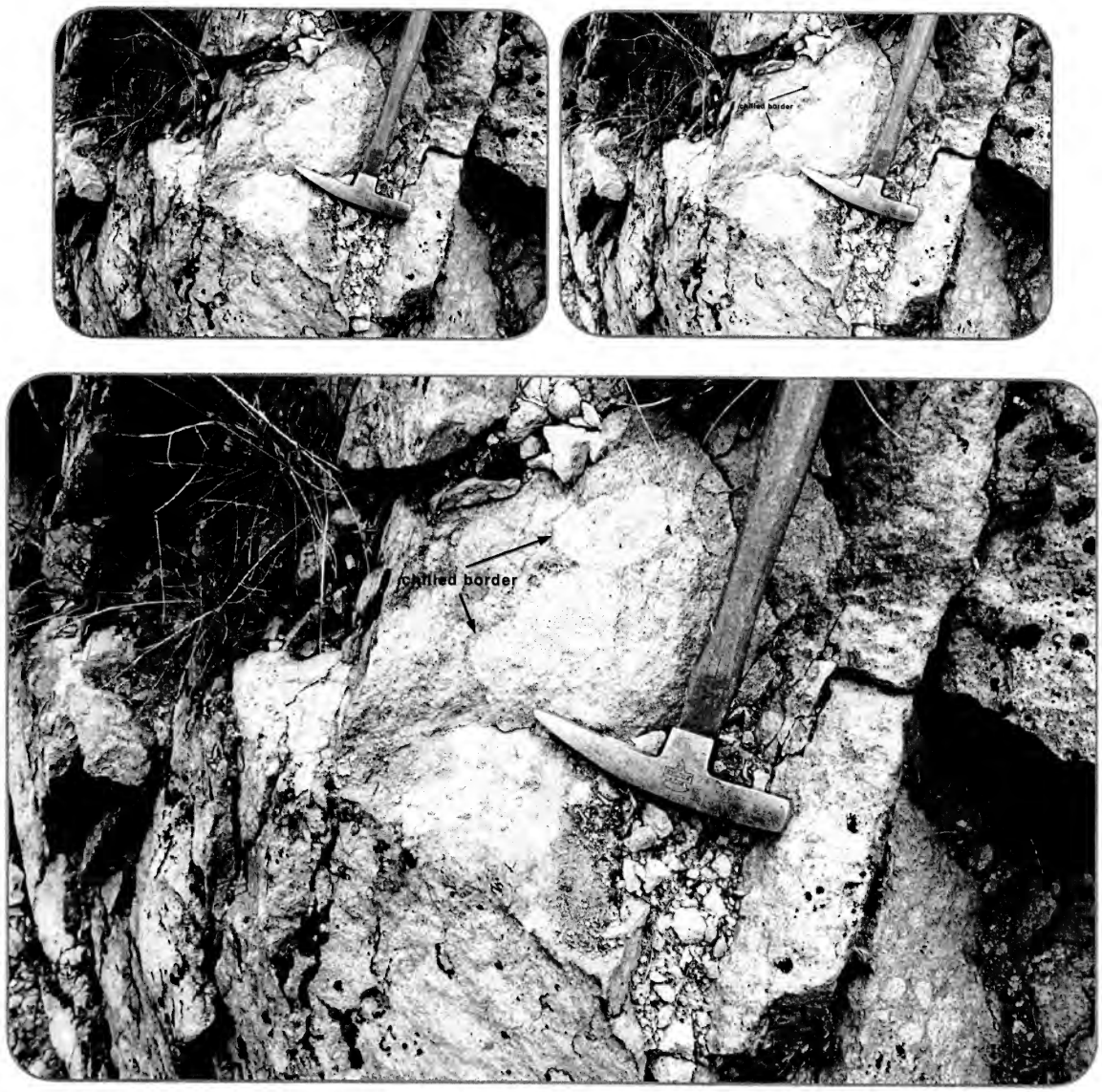




The dashed lines outline large and small rhyolite fragments in a crystal-fragment matrix of rhyolite. Left image = plane polarized light; right image = crossed polarizers. Magnification is about 50x.

Big Butte volcanics Stop 6

Chilled Border



The groundmass of the breccia consists of crystal-fragment rhyolite that is chilled next to some of the larger rounded rhyolite fragments.

Big Butte volcanics Stop 6

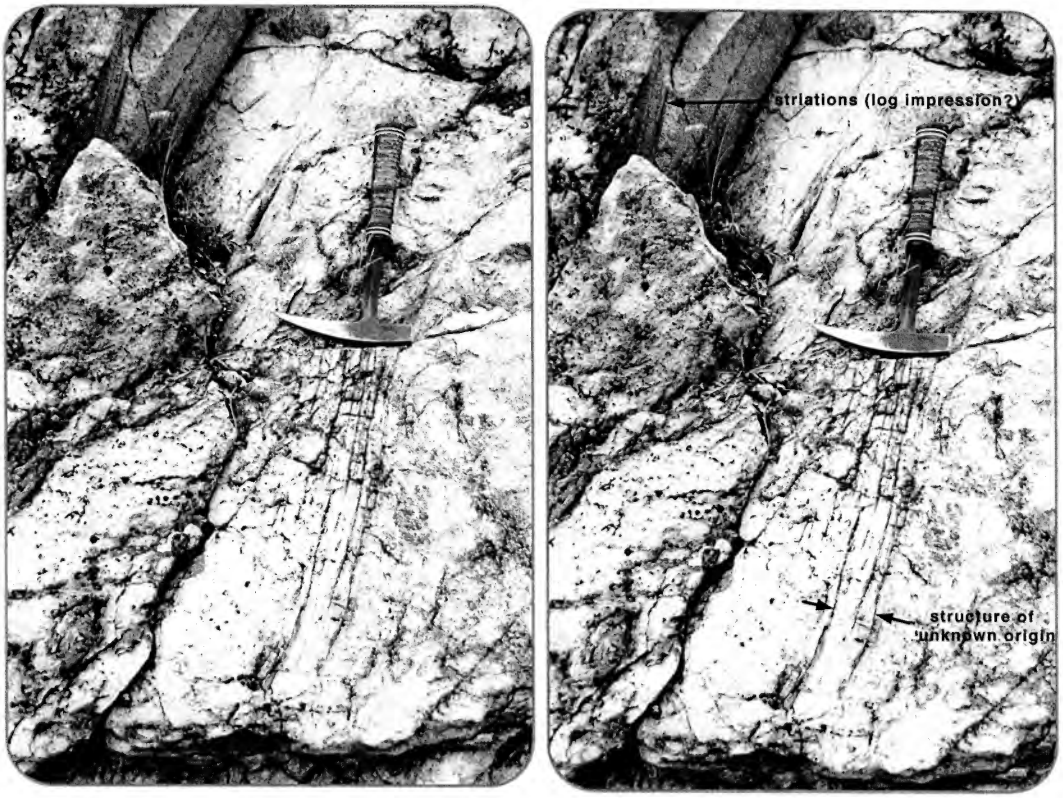
Stretched Rhyolite Fragments

Fragments of white-weathering rhyolite are locally aligned and stretched parallel to the foliation.

Big Butte volcanics Stop 6

Aligned Rhyolite Fragments & Striated Rhyolite

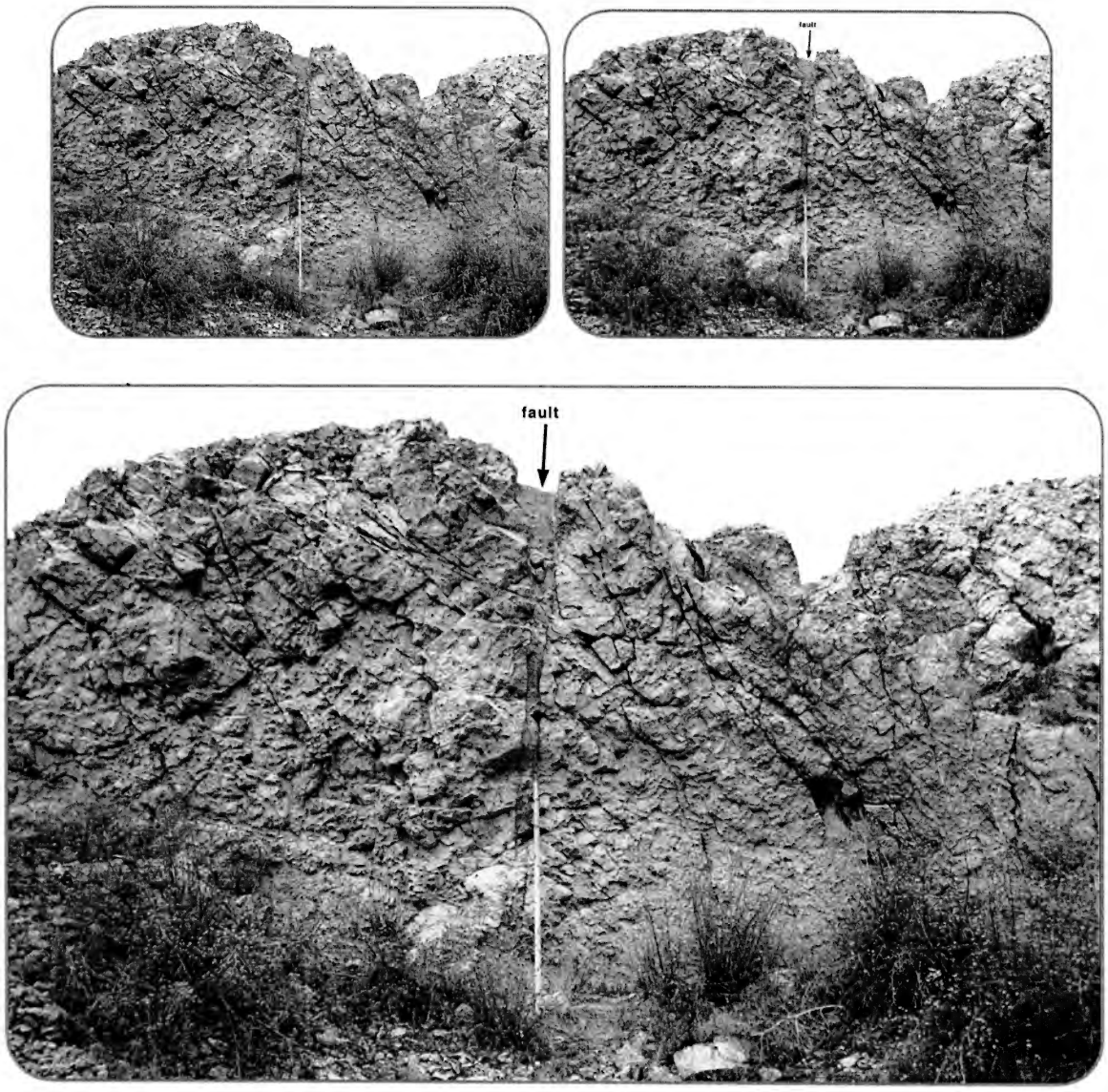
Aligned, white-weathering, rounded, rhyolite fragments define foliation.



Striations in the upper left dip at about 70 degrees, and occur on an elongated concave surface that might be the impression of a stick or small log that burned up in the rhyolite. The other set of parallel grooves is a structure of unknown origin.

Big Butte volcanics Stop 6

Fault Cuts Rhyolite Breccia



A fault of small but unknown displacement cuts rhyolite breccia in the west wall of the quarry.

Big Butte volcanics Stop 7

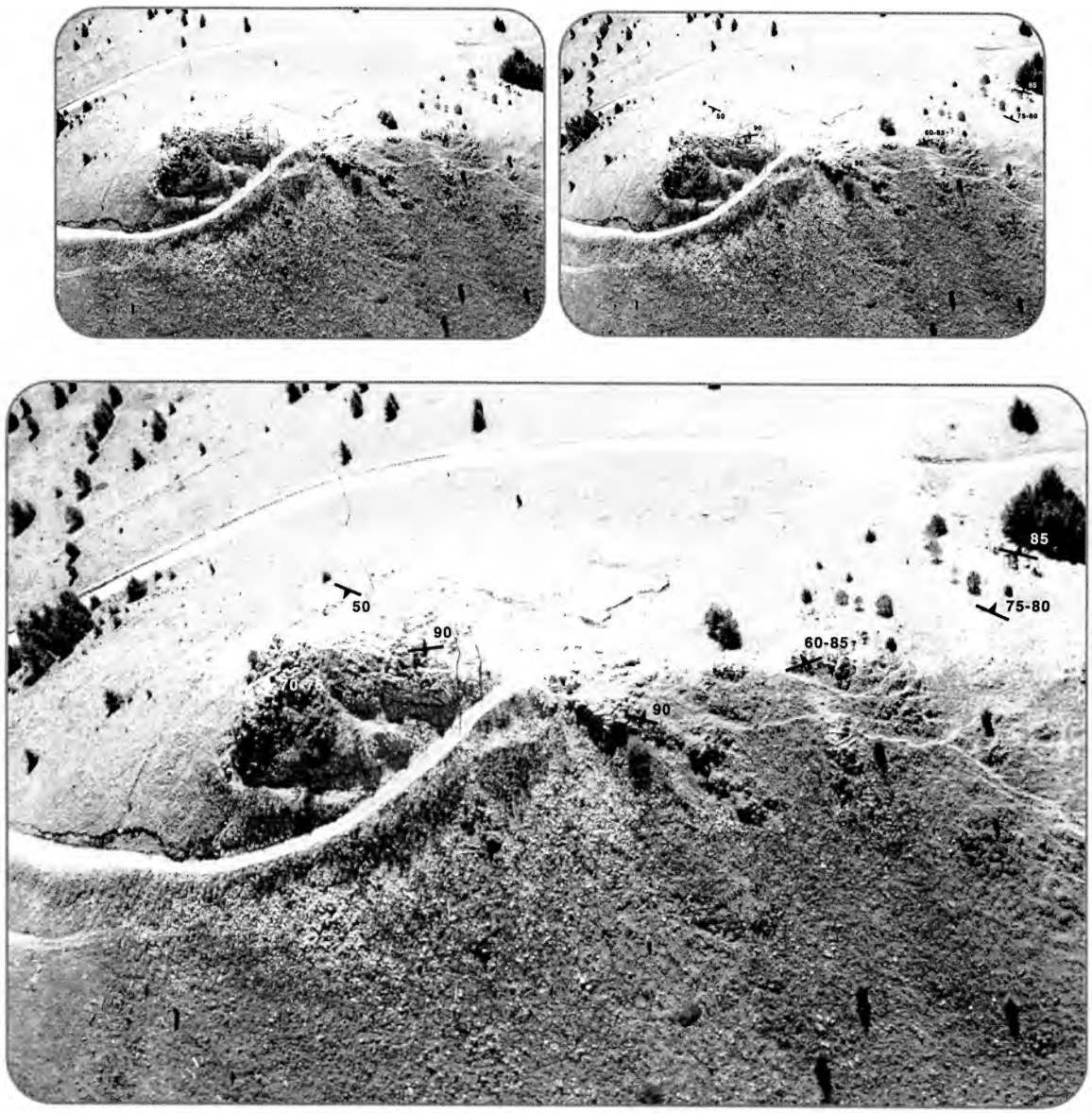
Consistent Foliation & Photomicrographs

Most of the foliation in the rhyolite that forms the top of Big Butte strikes northeast and is nearly vertical. Strikes range from N 50 E to N 10 W, and dips from 50 to 90 degrees.

Photomicrographs of rhyolite from the top of Big Butte show crystal fragments of feldspar, quartz, and biotite embedded in a glassy to finely crystalline groundmass. The left image was taken with plane polarized light; the right image used crossed polarizers. Magnification is about 50x.

Big Butte volcanics Stop 7

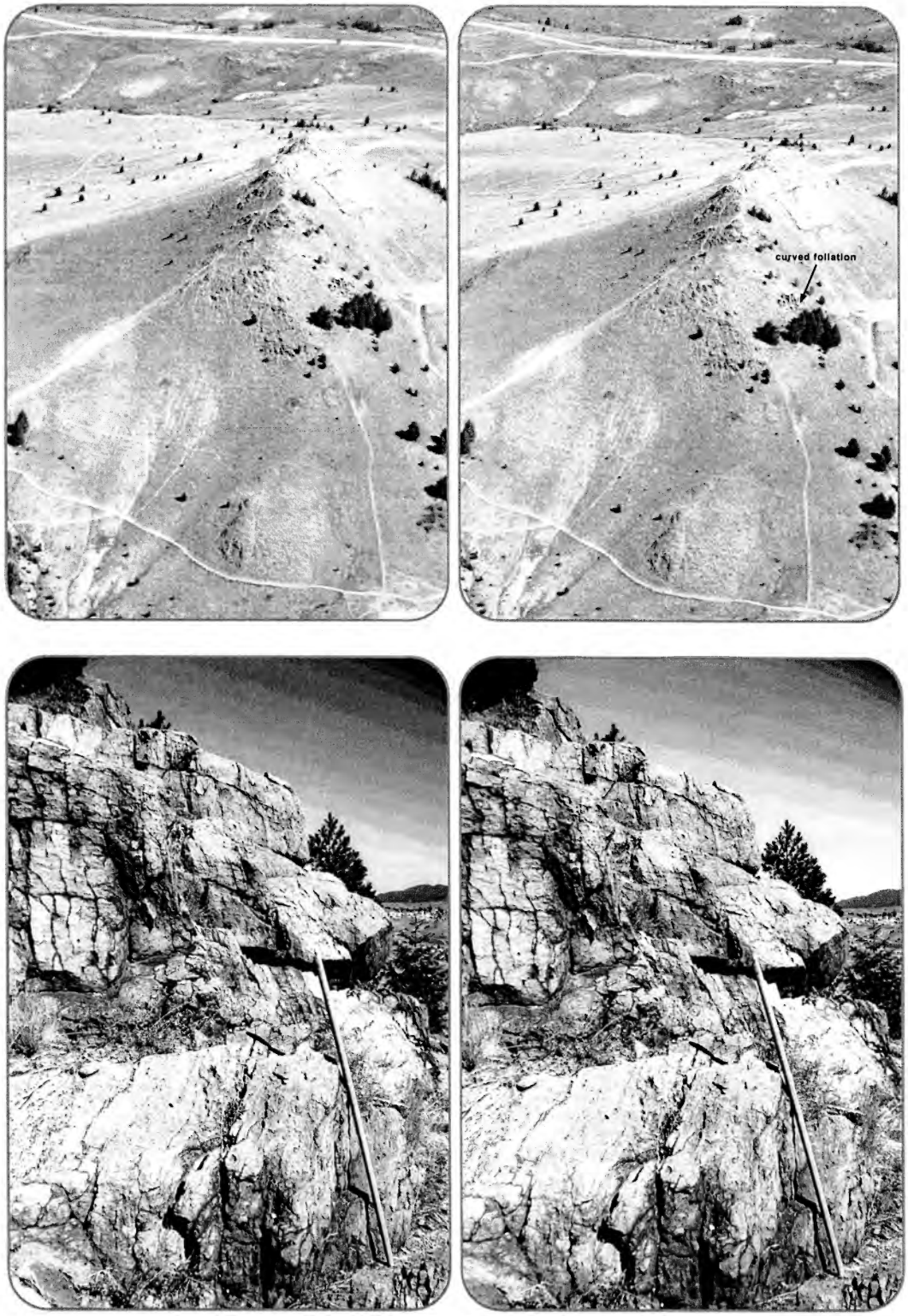
Consistent Foliation



You are looking eastward at the top of Big Butte. Its rhyolite is interpreted to be the filling of a conduit by steeply-dipping foliated rhyolite that froze while it was rising to be extruded after magma chamber explosions had broken its crystals. It is possible to imagine that the lava in the conduit may have fed a spine that rose irregularly, like a giant bottle stopper, at the top of the volcano to mark the end of the eruptions. Earlier, the conduit probably supplied the ash flows and lava flows that surround Big Butte.

Big Butte volcanics Stop 7

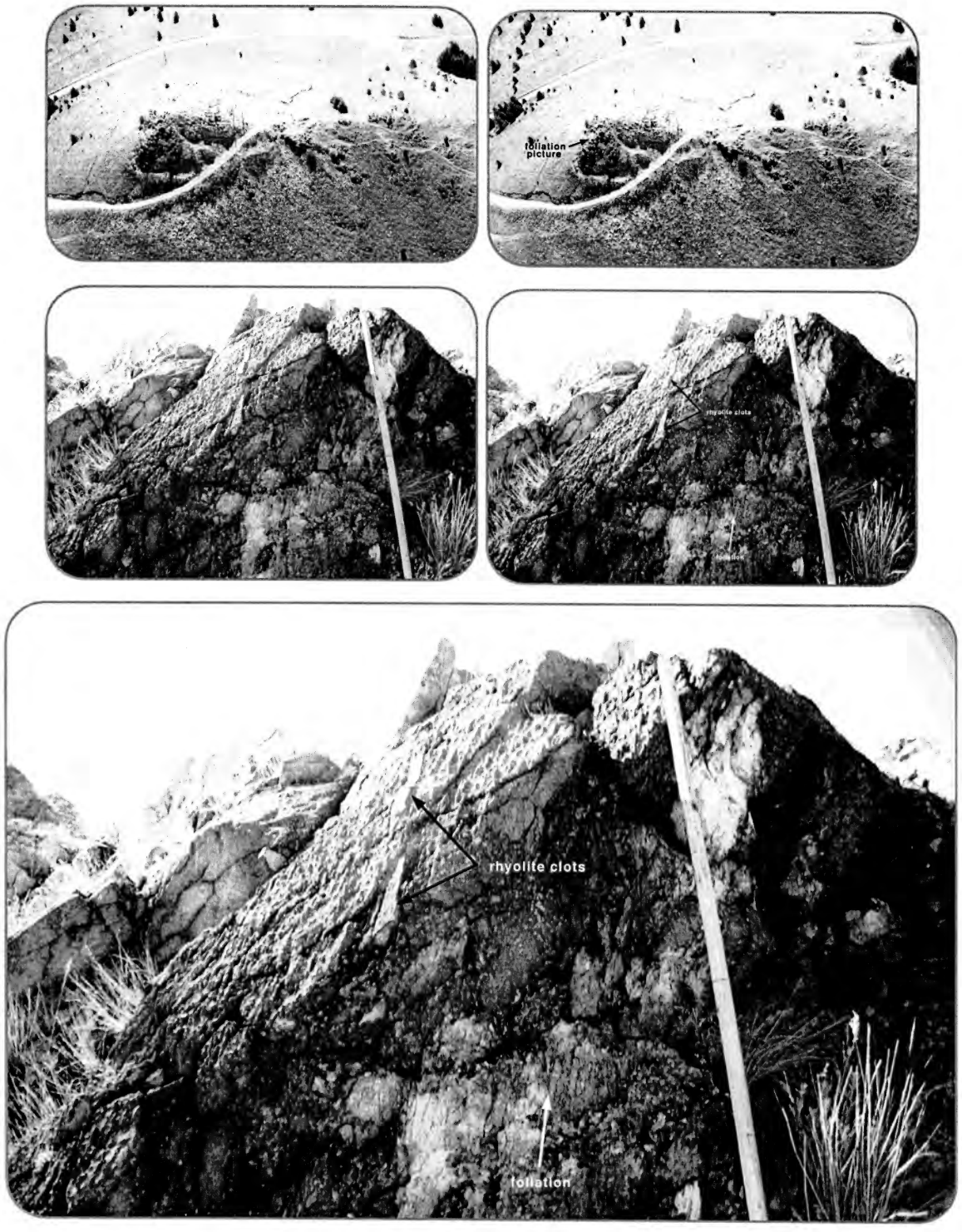
Curved Foliation



The strike of the foliation curves from N 45 E in the foreground to N 30 E in the background while the dip remains at about 85 degrees toward the southeast. Upward flow parallel to a curved portion of the conduit wall may have produced the foliation.

Big Butte volcanics Stop 7

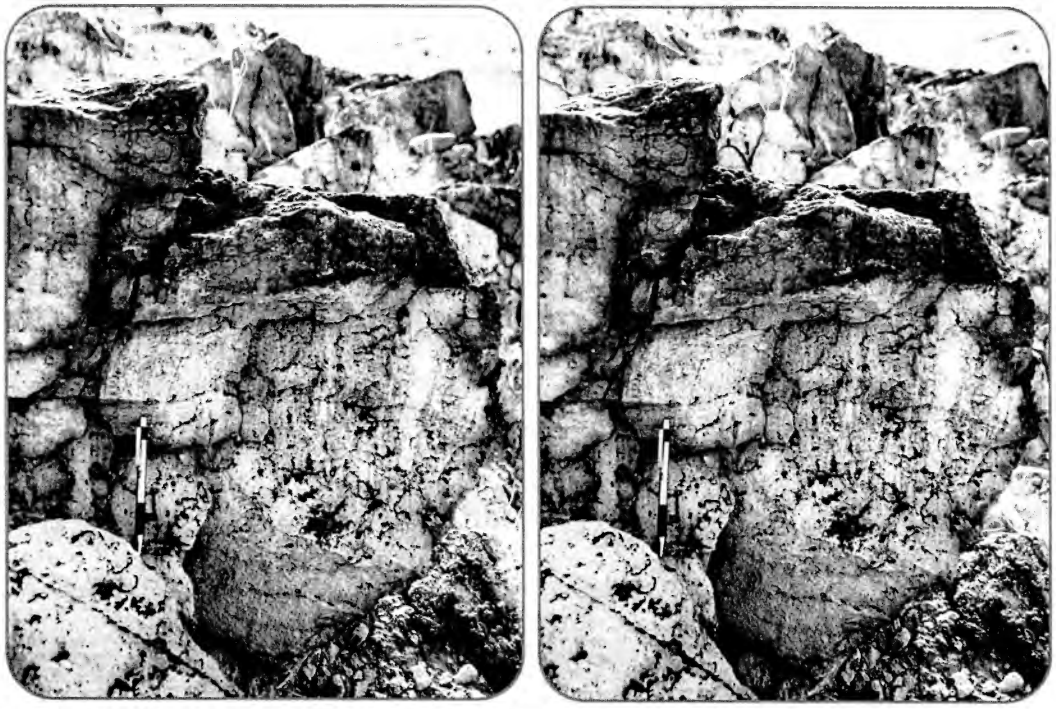
Foliation Defined by Rhyolite Clots & Ribs



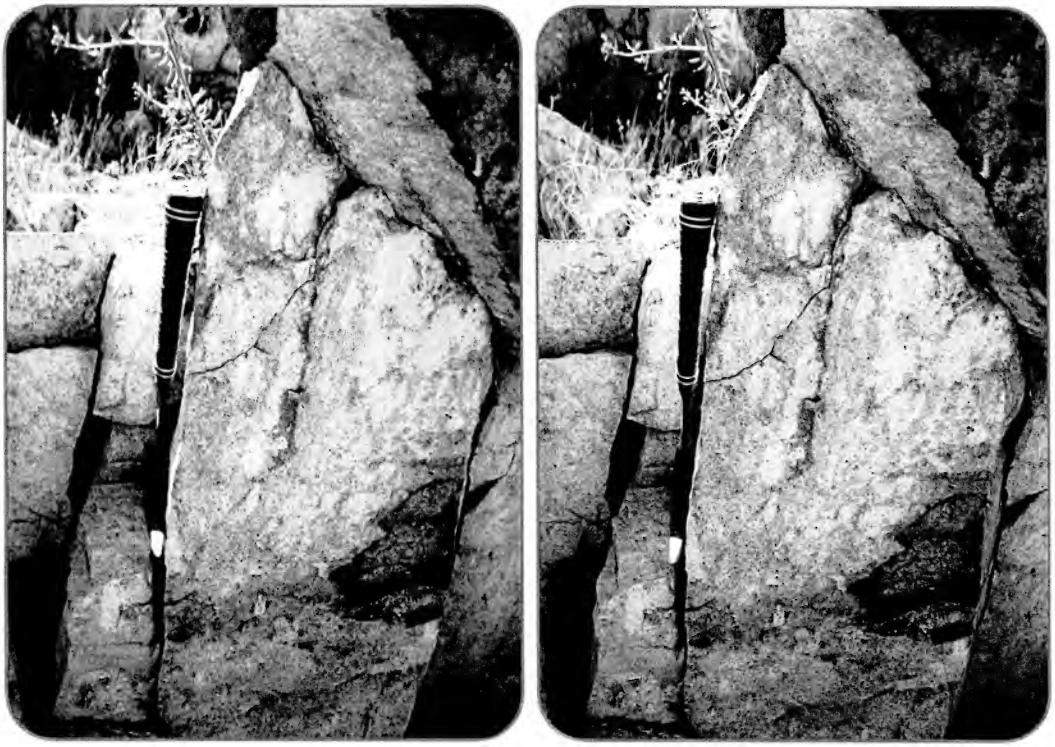
An irregularly-ribbed weathering pattern and elongated clots follow steeply-dipping foliation in rhyolite on the north face of Big Butte near its top.

Big Butte volcanics Stop 7

Foliation Defined by Clots, Lenses, and Lamellae



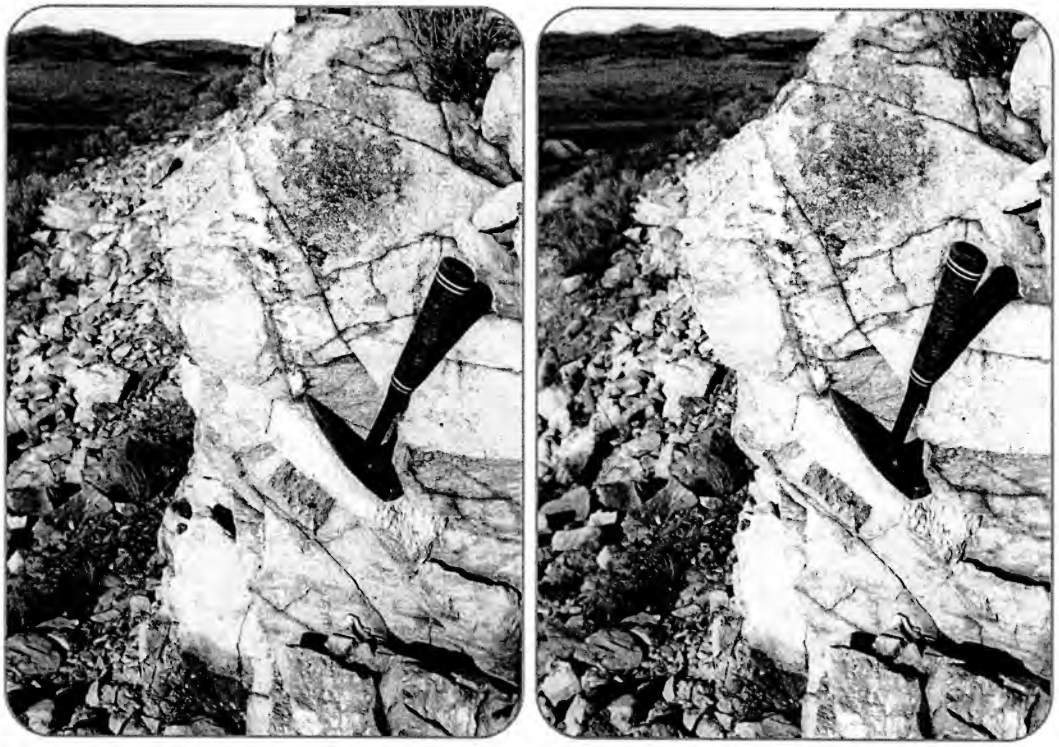
Whitish clots, lenses, and lamellae of rhyolite define vertical foliation within the rhyolite at the top of Big Butte.



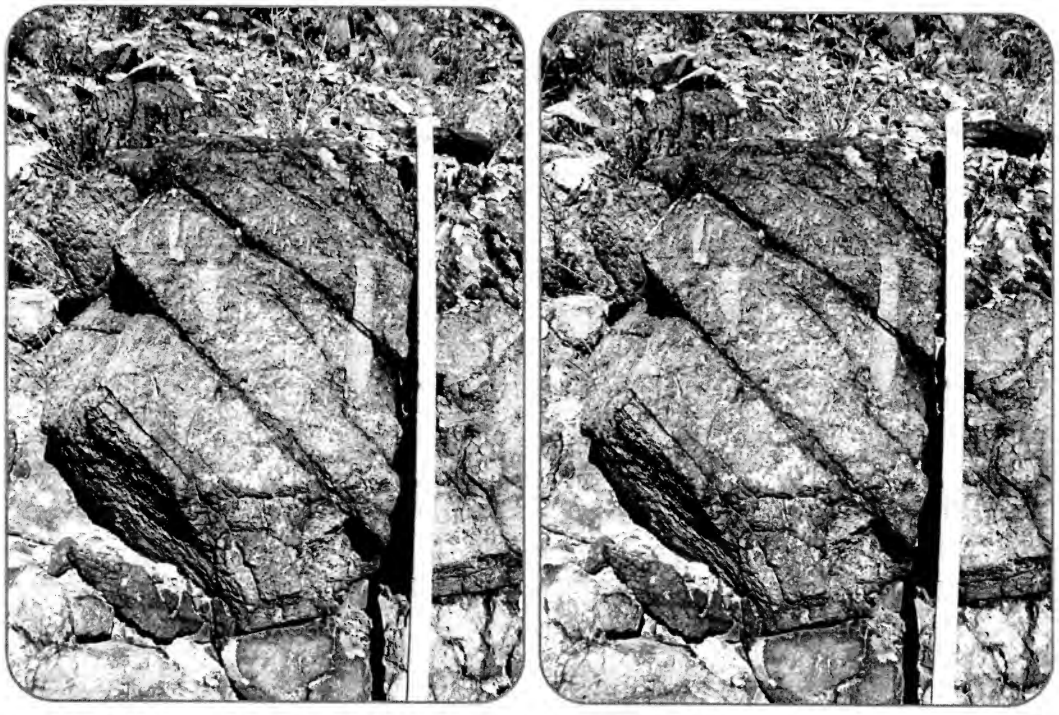
You are looking perpendicular to the foliation at white lamellae of rhyolite flattened on vertical foliation surfaces at the top of Big Butte.

Big Butte volcanics Stop 7

Foliation Defined by Clots



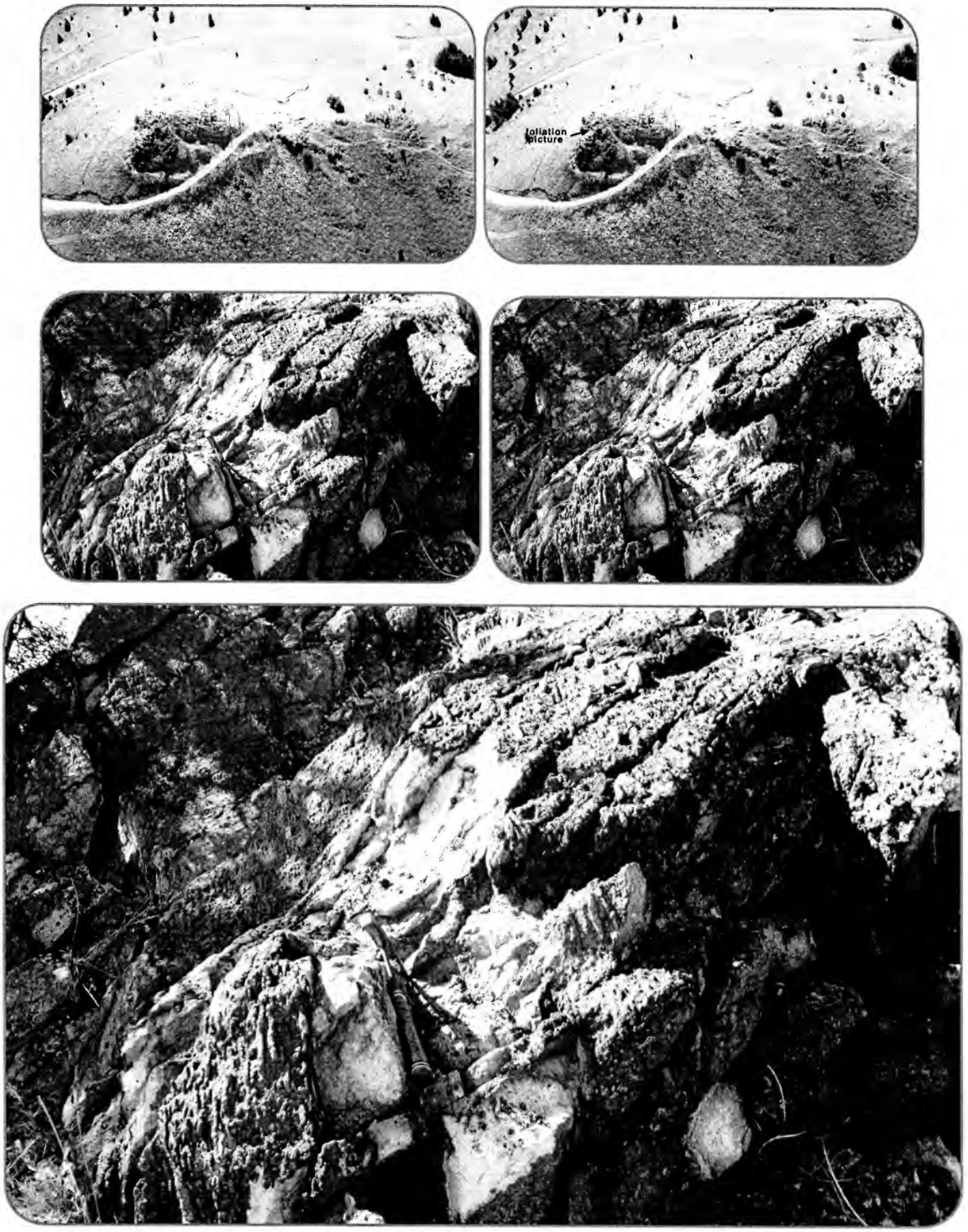
A lens-shaped clot of foliated white rhyolite is aligned along near vertical foliation in the rhyolite at the top of Big Butte.



Large and small, lens-shaped clots of rhyolite define vertical foliation on the southwest side of Big Butte.

Big Butte volcanics Stop 7

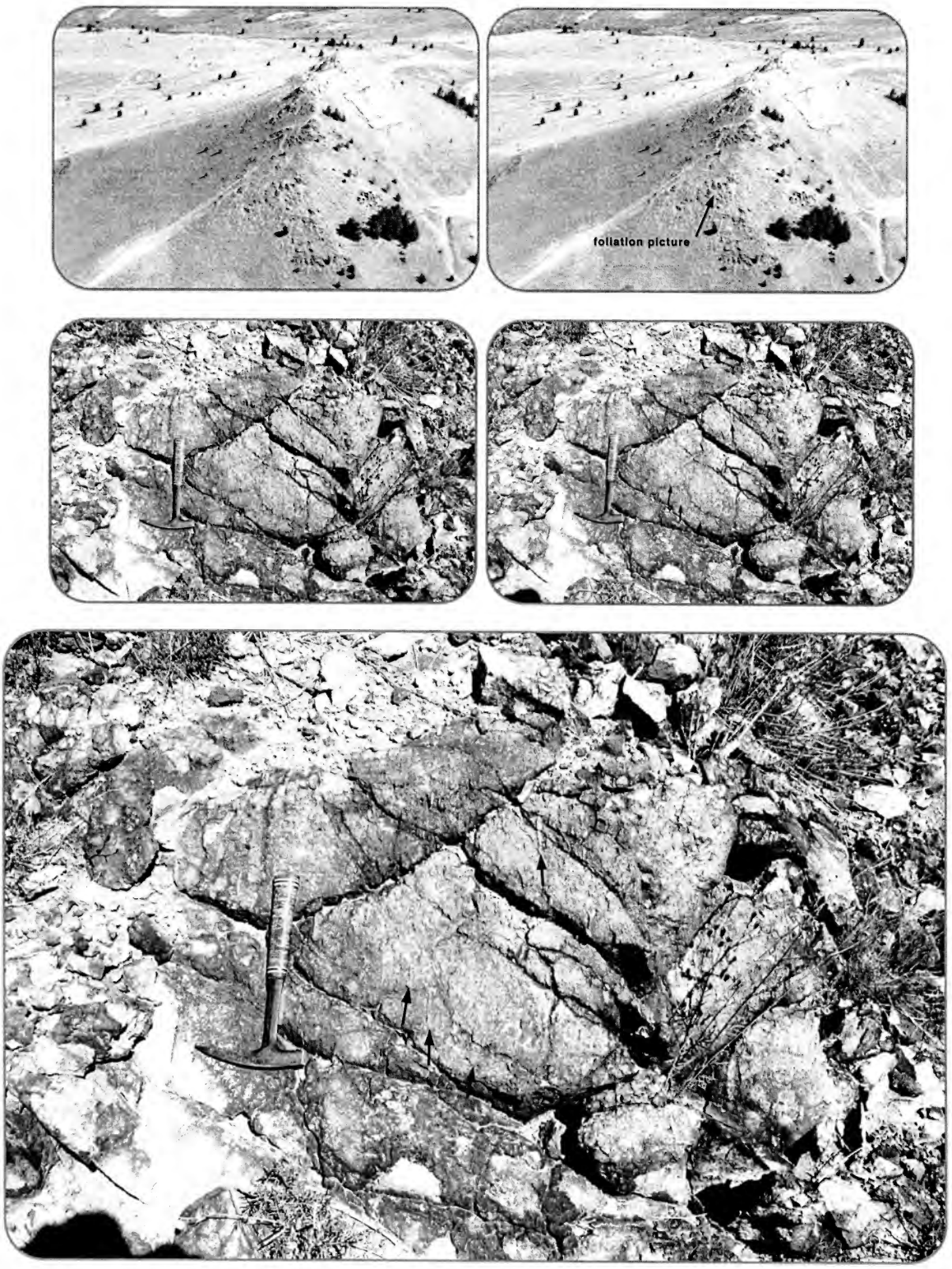
Aligned Clots Define Foliation



Steeply dipping foliation is defined on weathered surfaces by the etching of less resistant rhyolite from between flattened and aligned clots and streaks of more resistant rhyolite.

Big Butte volcanics Stop 7

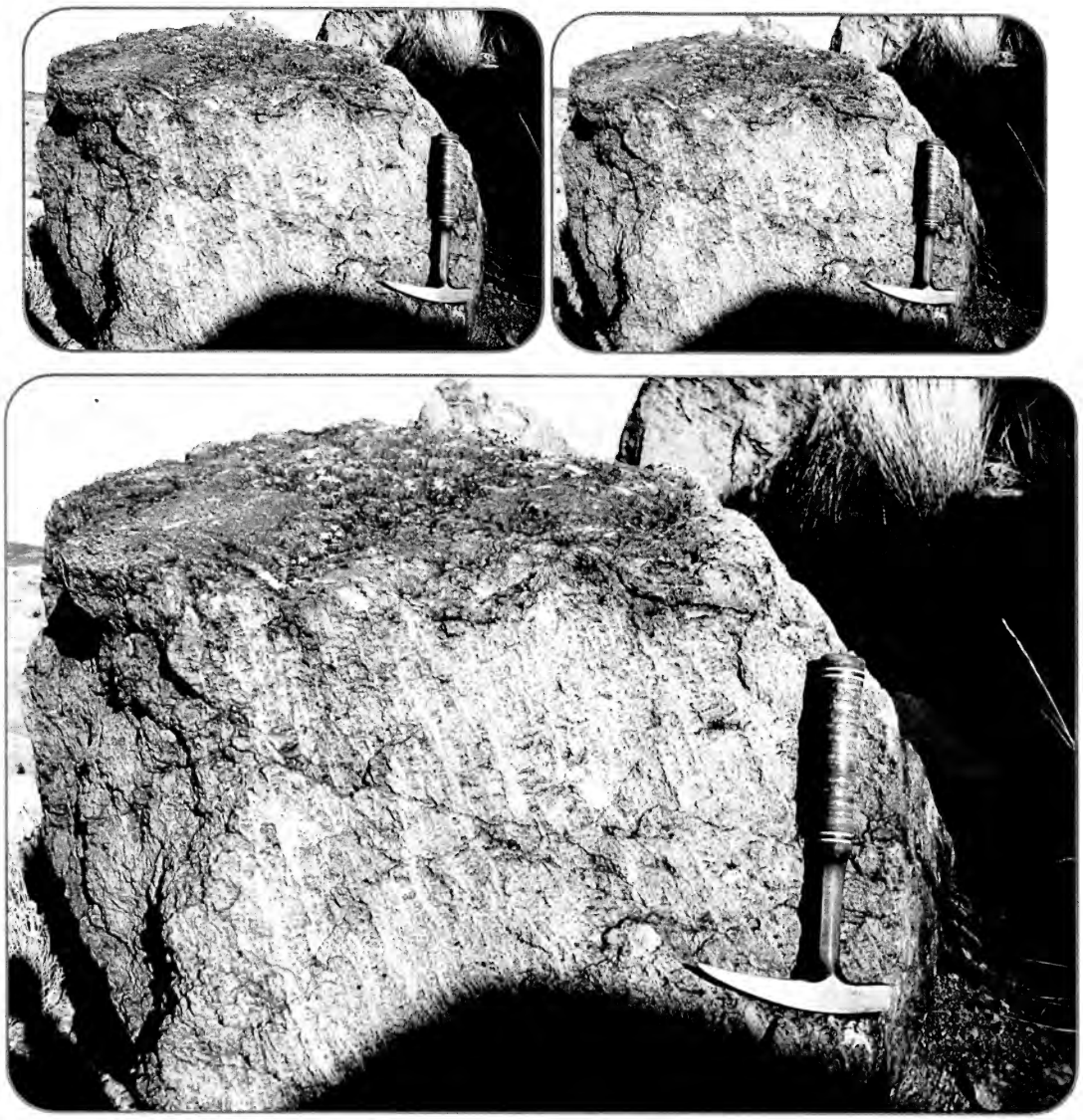
Aligned Clots



Arrows point to a few of the flattened and aligned clots that define vertical foliation in the rhyolite on the southwest side of Big Butte.

Big Butte volcanics Stop 7

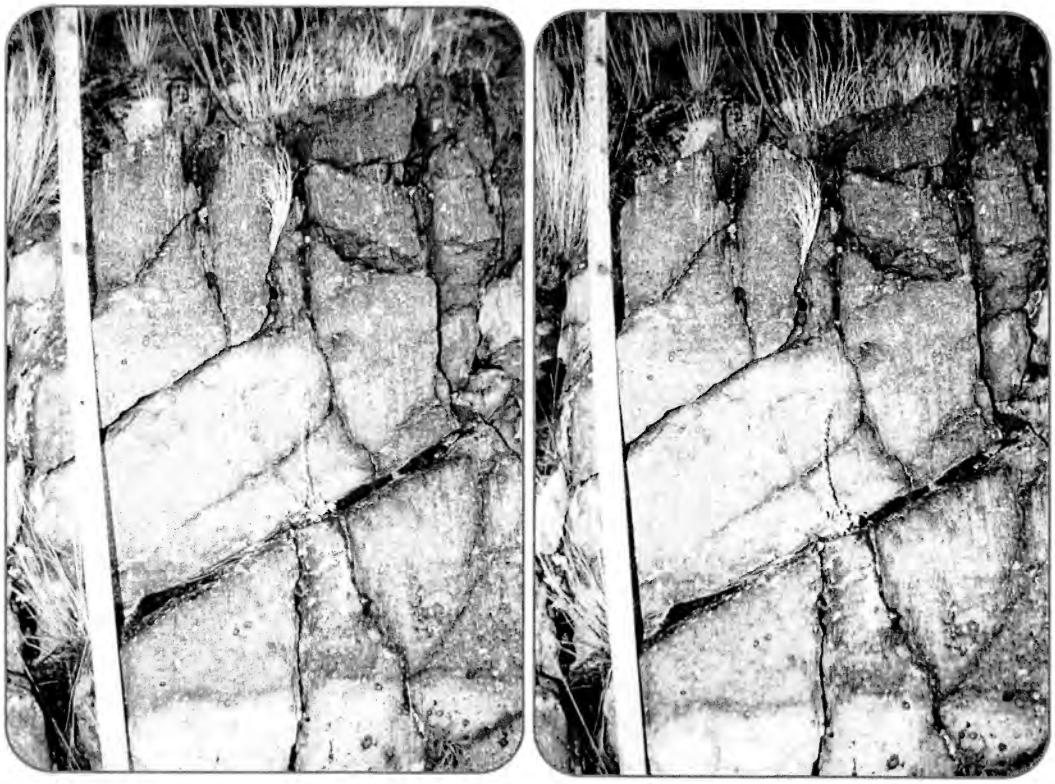
Rhyolite Lamellae & Clots Define Foliation



Irregular, overlapping, discontinuous lamellae of harder rhyolite define steeply-dipping foliation on the north face of Big Butte near its top.

Big Butte volcanics Stop 7

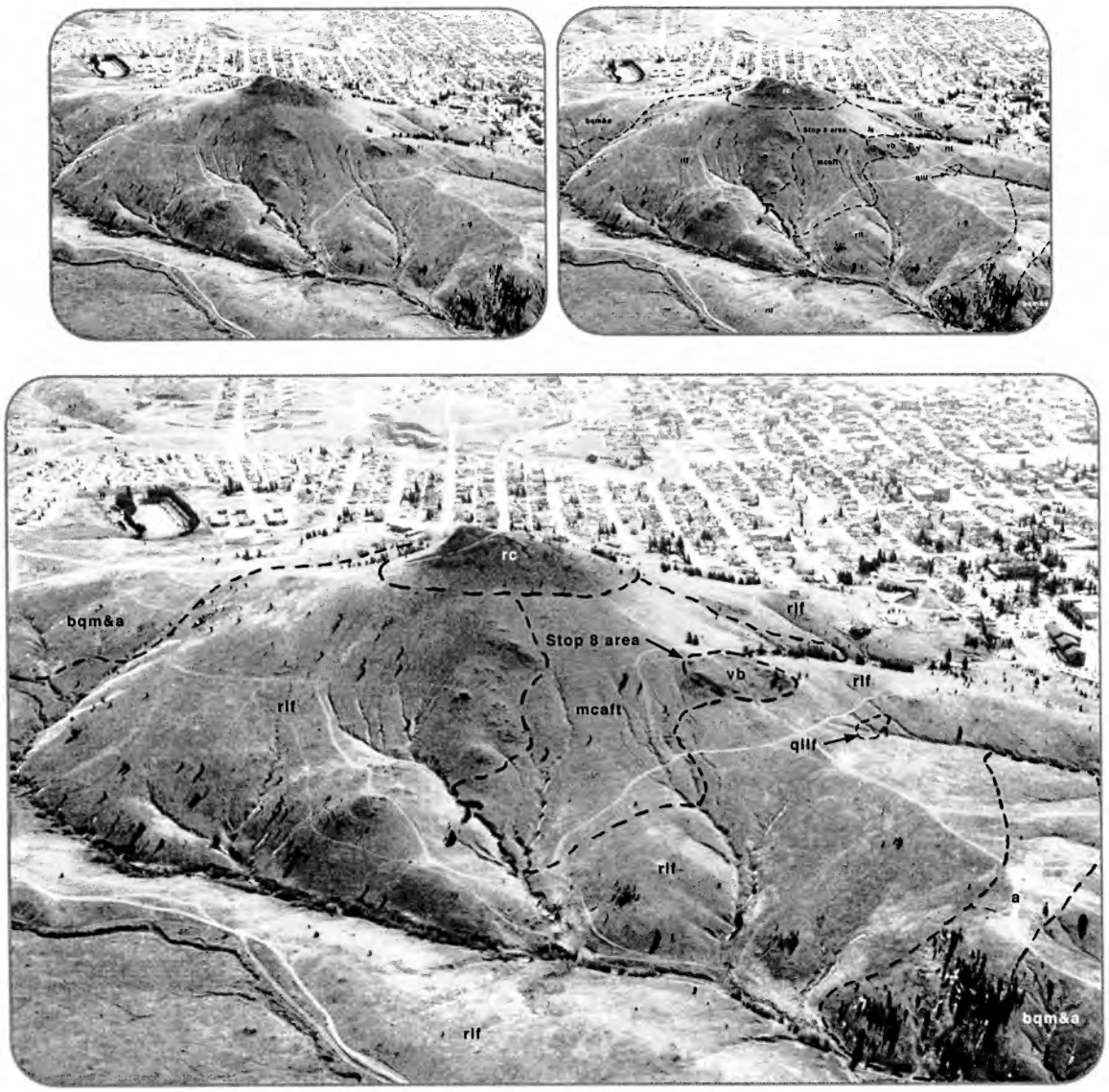
Rhyolite Lamellae Define Foliation



Vertical light-colored streaks on the weathered face are irregular thin lamellae of slightly harder rhyolite that define vertical foliation on the north face of Big Butte near its top.

Big Butte volcanics Stop 8

Oblique Photomap

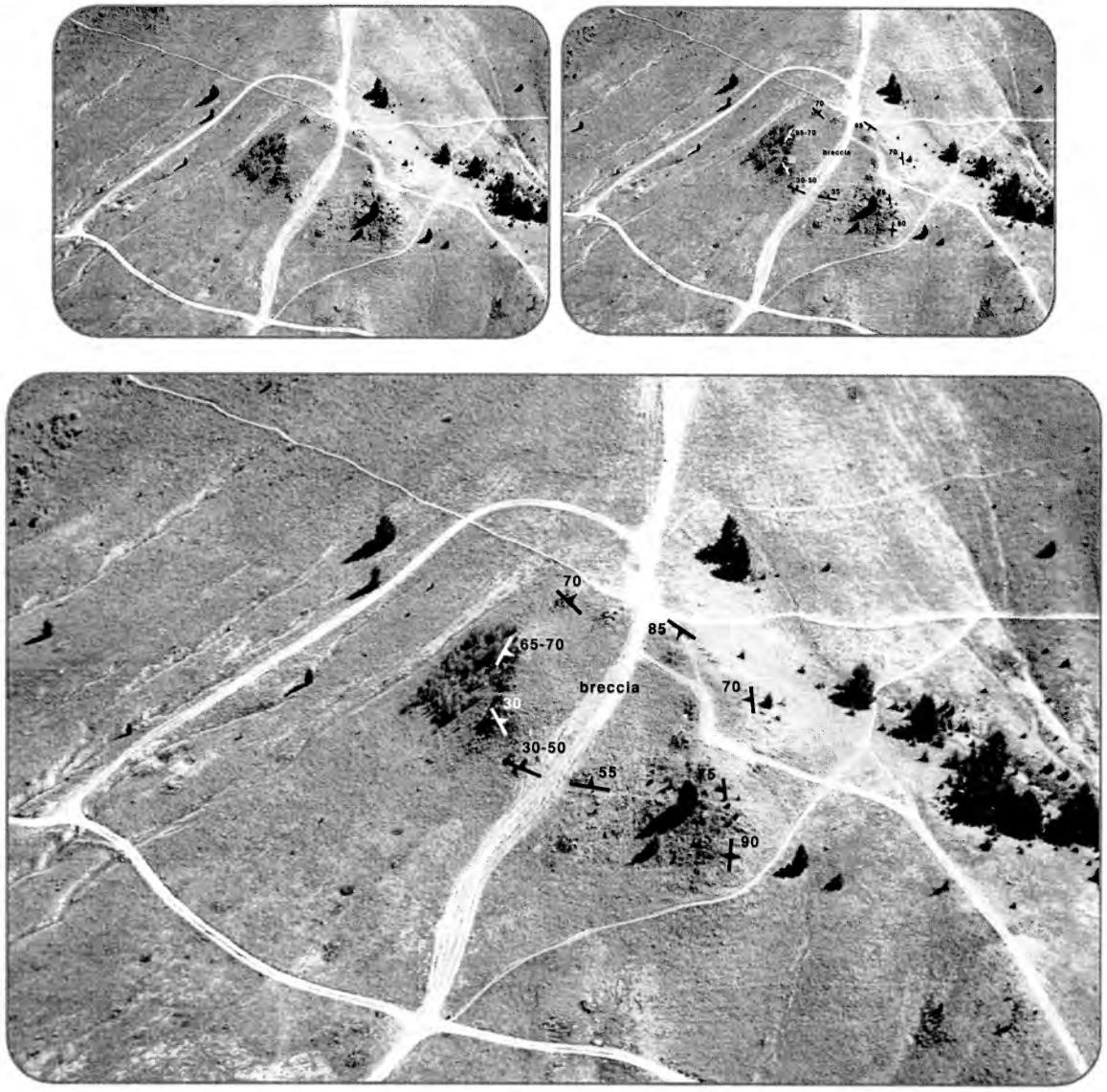


You are looking eastward at Big Butte and its rhyolites.

a = aplite bqm&a = butte quartz monzonite and aplite mcaft = mostly covered ash flow tuff qllf = quartz latite lava flow rc = rhyolite conduit rlf = rhyolite lava flow vb = vent breccia

Big Butte volcanics Stop 8

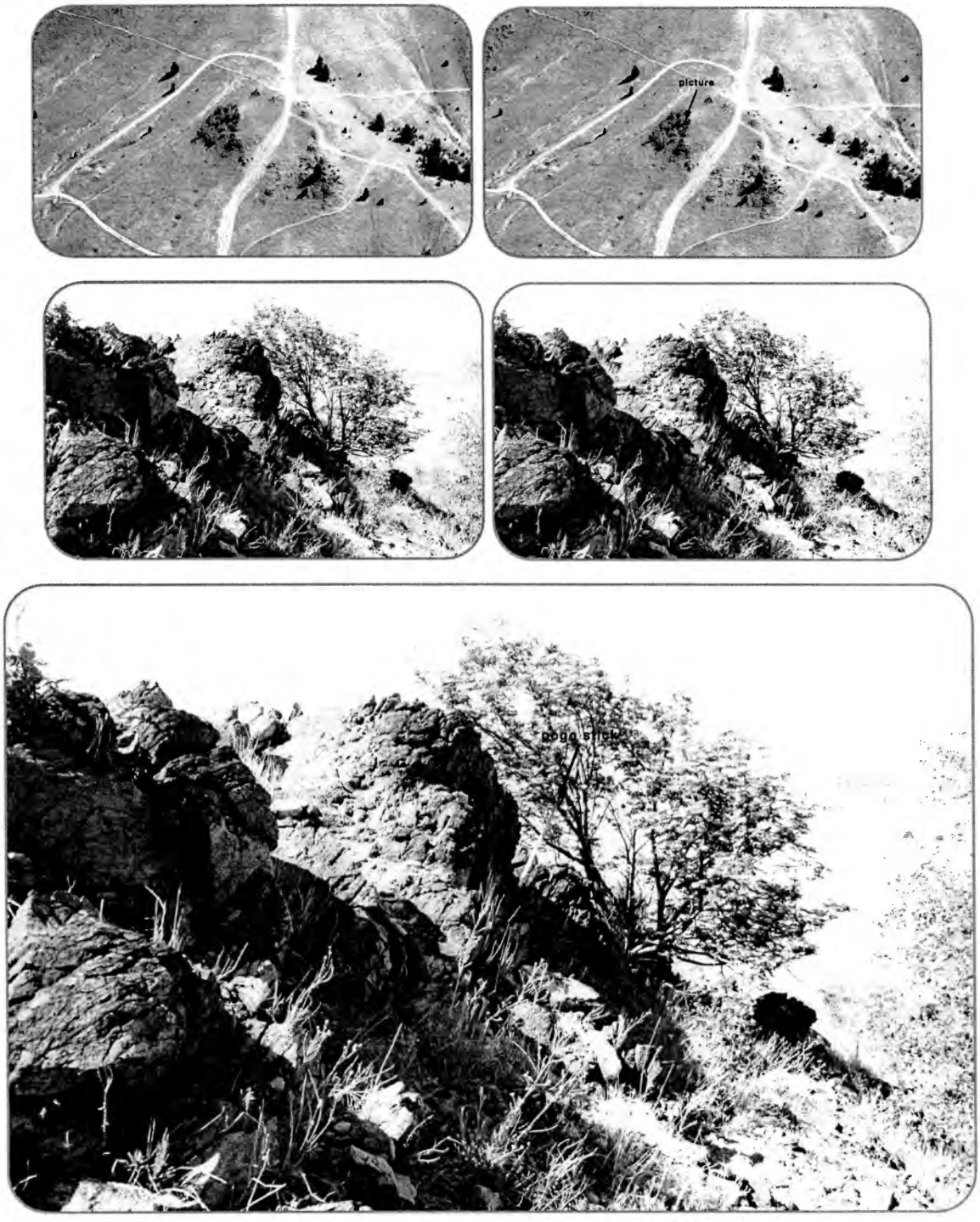
Oblique Photomap of Foliation Around Vent



Foliated rhyolite surrounds a core of breccia that contains reddish rhyolite and fragments of aplite. Most of the foliation dips steeply inward toward the center of the structure. It is interpreted to be a small parasitic funnel-shaped vent.

Big Butte volcanics Stop 8

Foliation on Northwest Side of Vent



You are looking toward the southwest at foliation that strikes northeast and dips steeply toward the southeast on the northwestern side of the vent breccia. The pogo stick propped in the tree parallel to the foliation is five feet long.

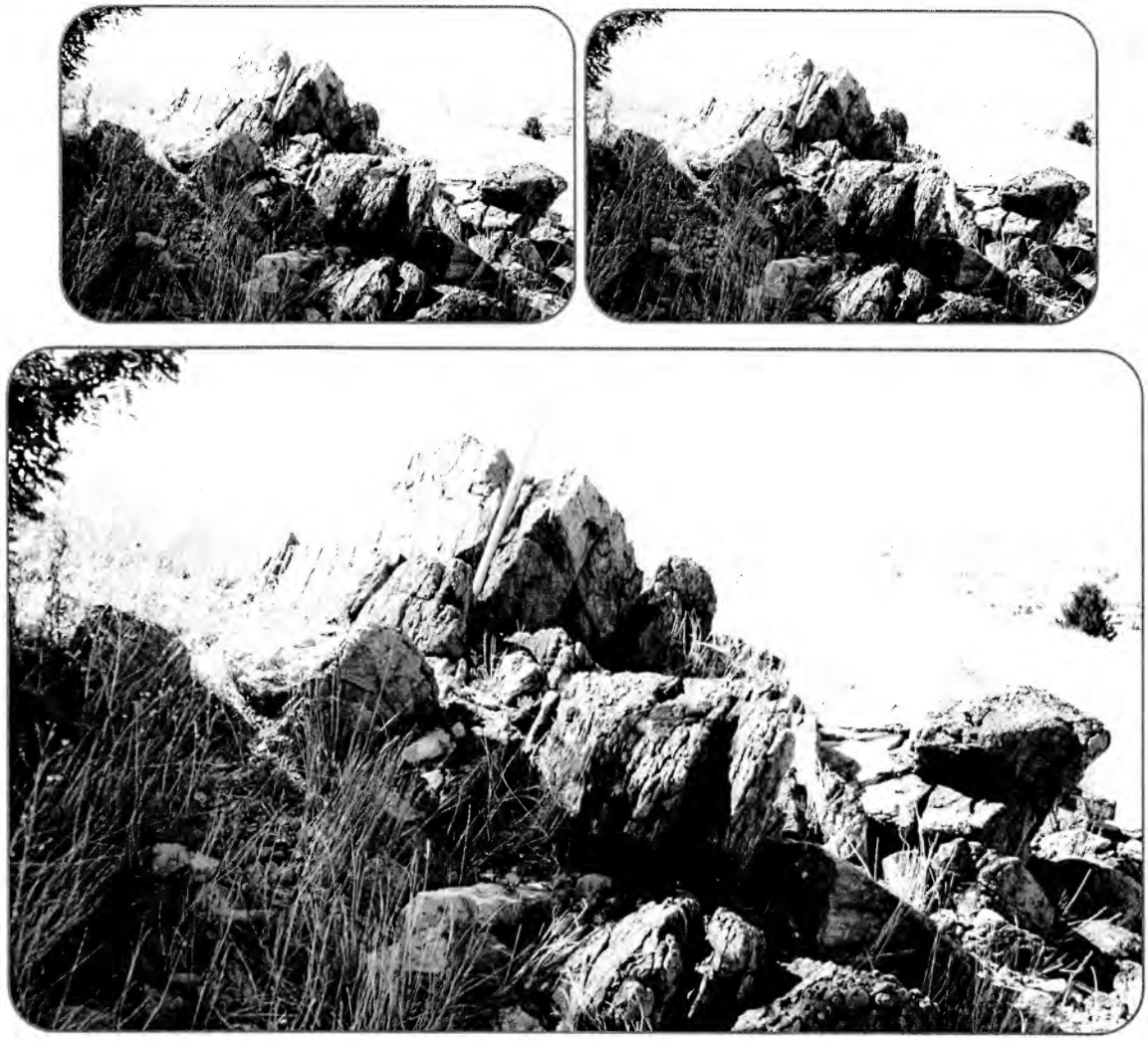
Big Butte volcanics Stop 8

Foliation at Southwest Corner of Vent

You are looking southward along strike at foliation that dips about 30 degrees eastward, toward the center of the vent breccia structure. The plane of the hammer is parallel to the foliation.

Big Butte volcanics Stop 8

Foliation at North Corner of Vent - Photomicrographs

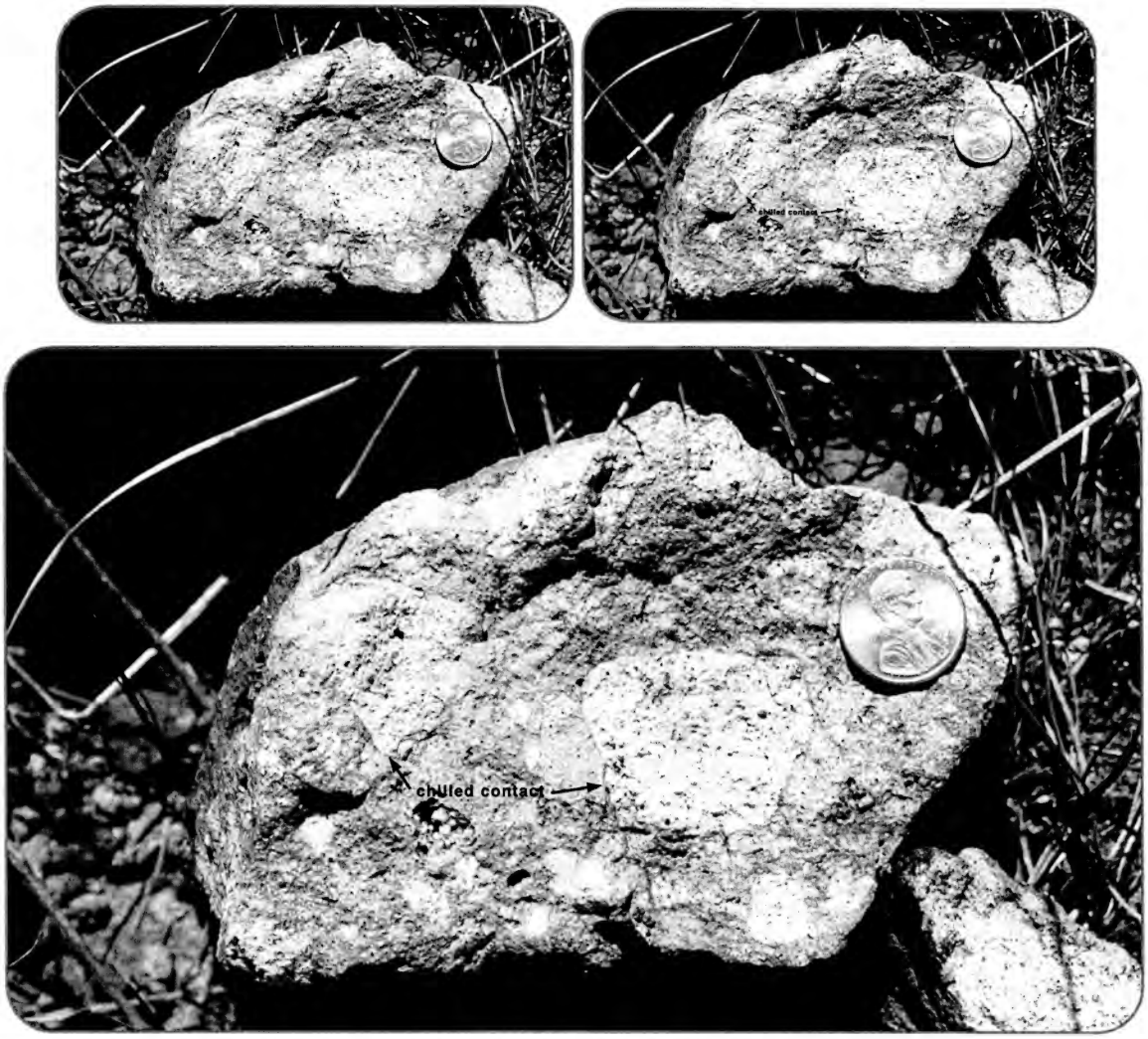


Foliation dips steeply away from the center of the vent breccia structure at the northern corner of the structure. You are looking southward.

The two photomicrographs are of the rock shown in the outcrop above. Fragments of feldspar, quartz, and biotite are embedded in a glassy to finely crystalline groundmass. Left image used plane polarized light; right image used crossed polarizers. Magnification is about 50x.

Big Butte volcanics Stop 8

Vent Breccia & Photomicrographs

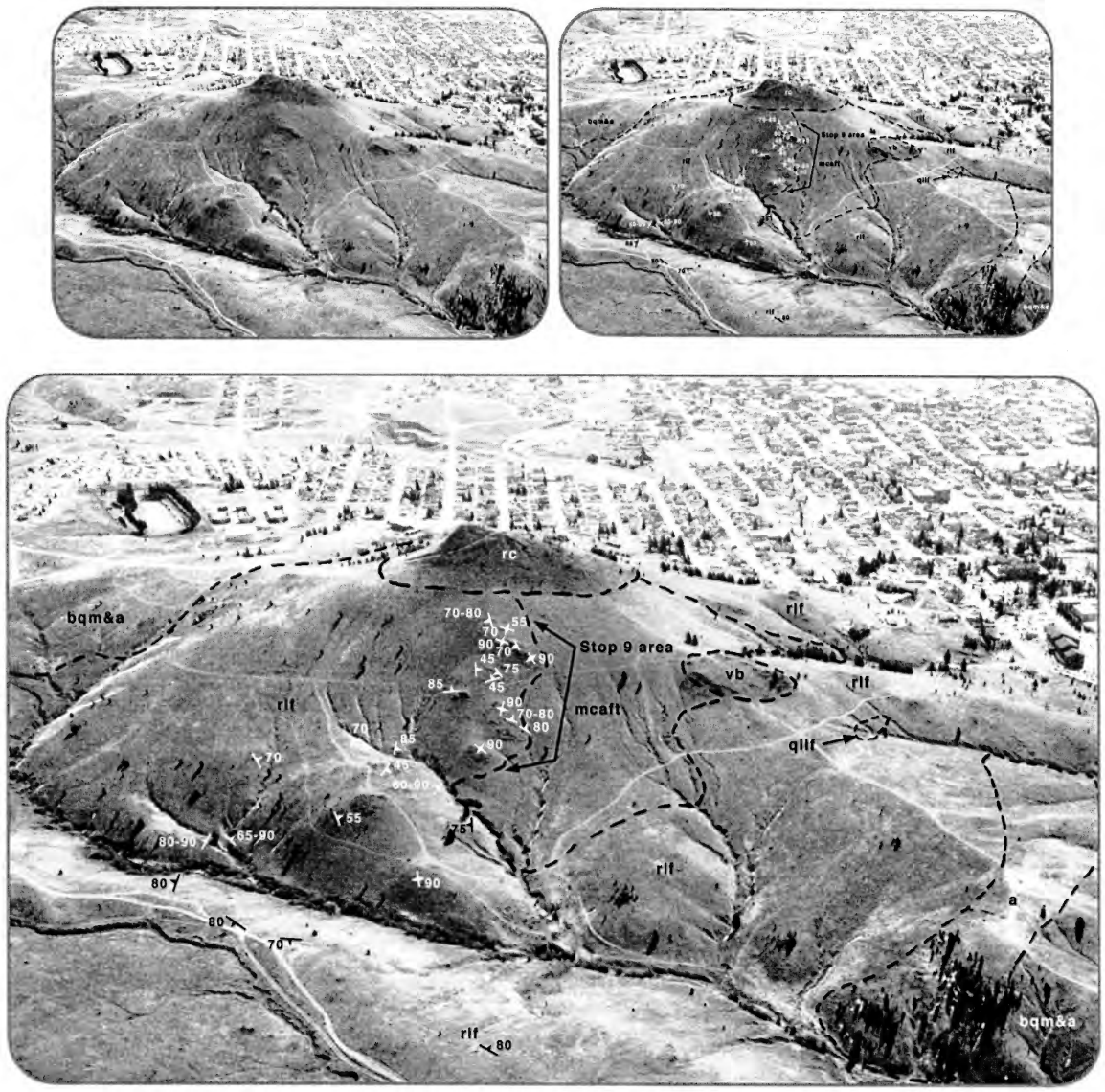


Fine-grained rhyolite flowed around fragments of rhyolite and aplite and chilled where it contacted the larger fragments torn from earlier deposits.

Near the center of the vent-breccia structure, chunks of aplite and red, iron-stained rhyolite are enclosed in a glassy to finely crystalline groundmass containing finely broken crystals of feldspar, quartz, and biotite. Left image used plane polarized light; right image used crossed polarizers. Magnification is about 50x.

Big Butte volcanics Stop 9

Variable Foliation in Lava Flow



The view is toward the east of a bulge on the side of Big Butte (Stop 9 area) that is interpreted to be part of a lava flow. The many diverse strikes and dips of its foliation are plotted on the picture. Some of the features that indicate it to be a lava flow are shown on the next three pages.

Big Butte volcanics Stop 9

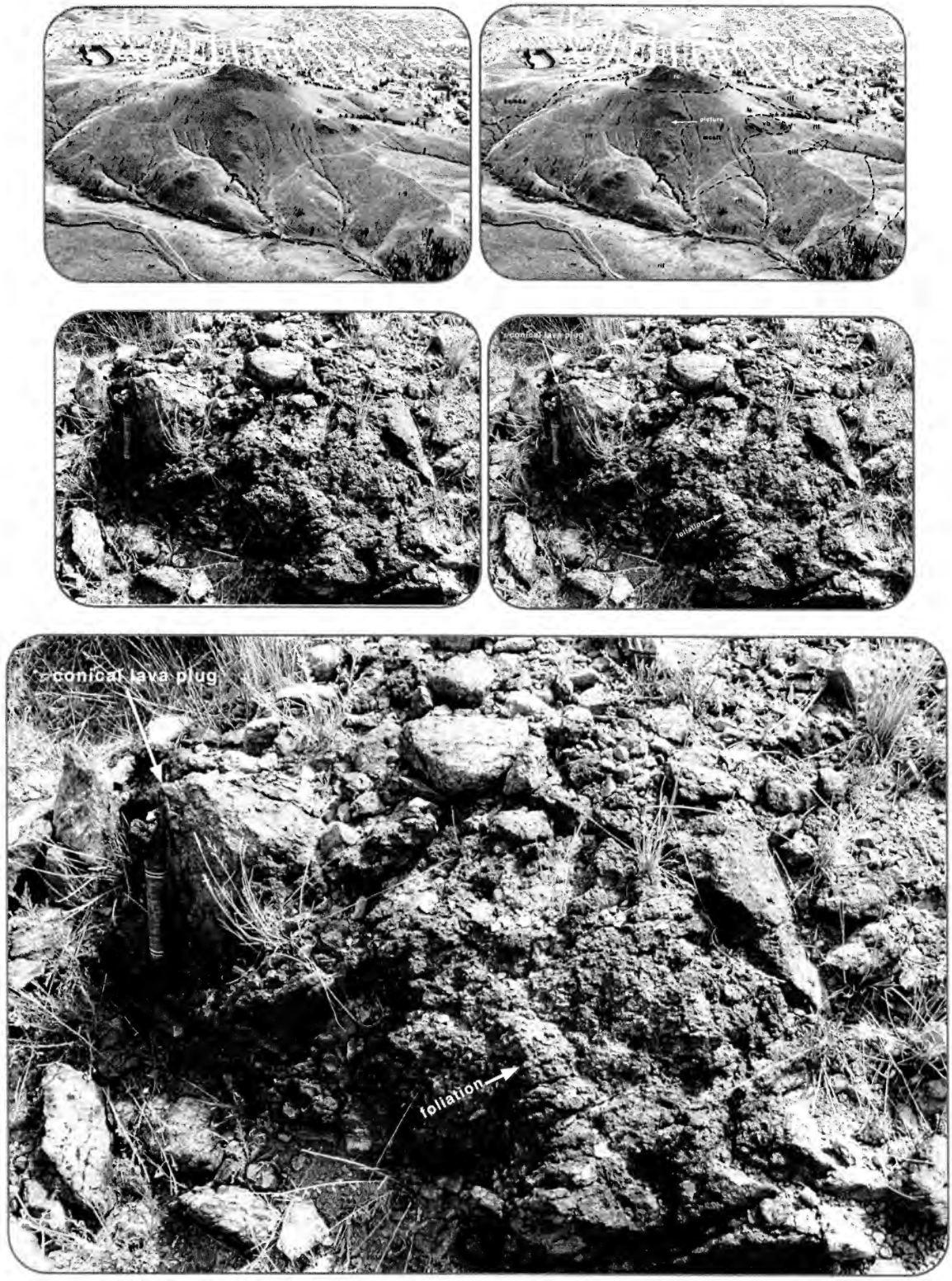
Scour Cuts Foliation - Photomicrographs of Lava

A small scour by fluid lava cut into foliation that is now vertical. The attitude of the foliation at the time it was scoured is not known.

Photomicrographs show crystal fragments in a reddish, iron-stained, finely-crystalline groundmass. Left picture used plane polarized light; right picture used crossed polarizers. Magnification is about 50x.

Big Butte volcanics Stop 9

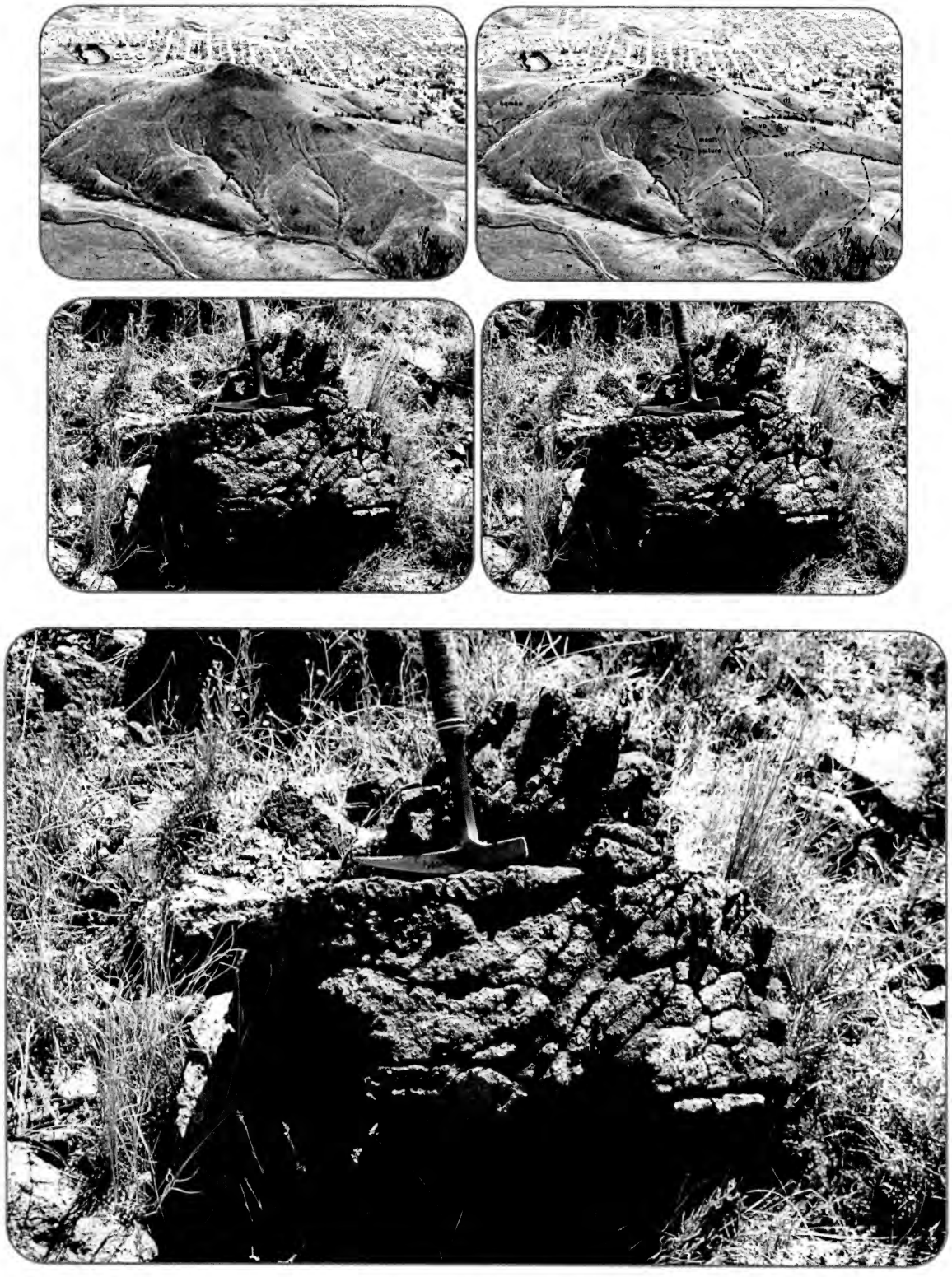
Conical Lava Plug Squirted into Breccia



Striations formed on the surface of a conical lava plug as it forced its way into a foliated breccia of small lava clots.

Big Butte volcanics Stop 9

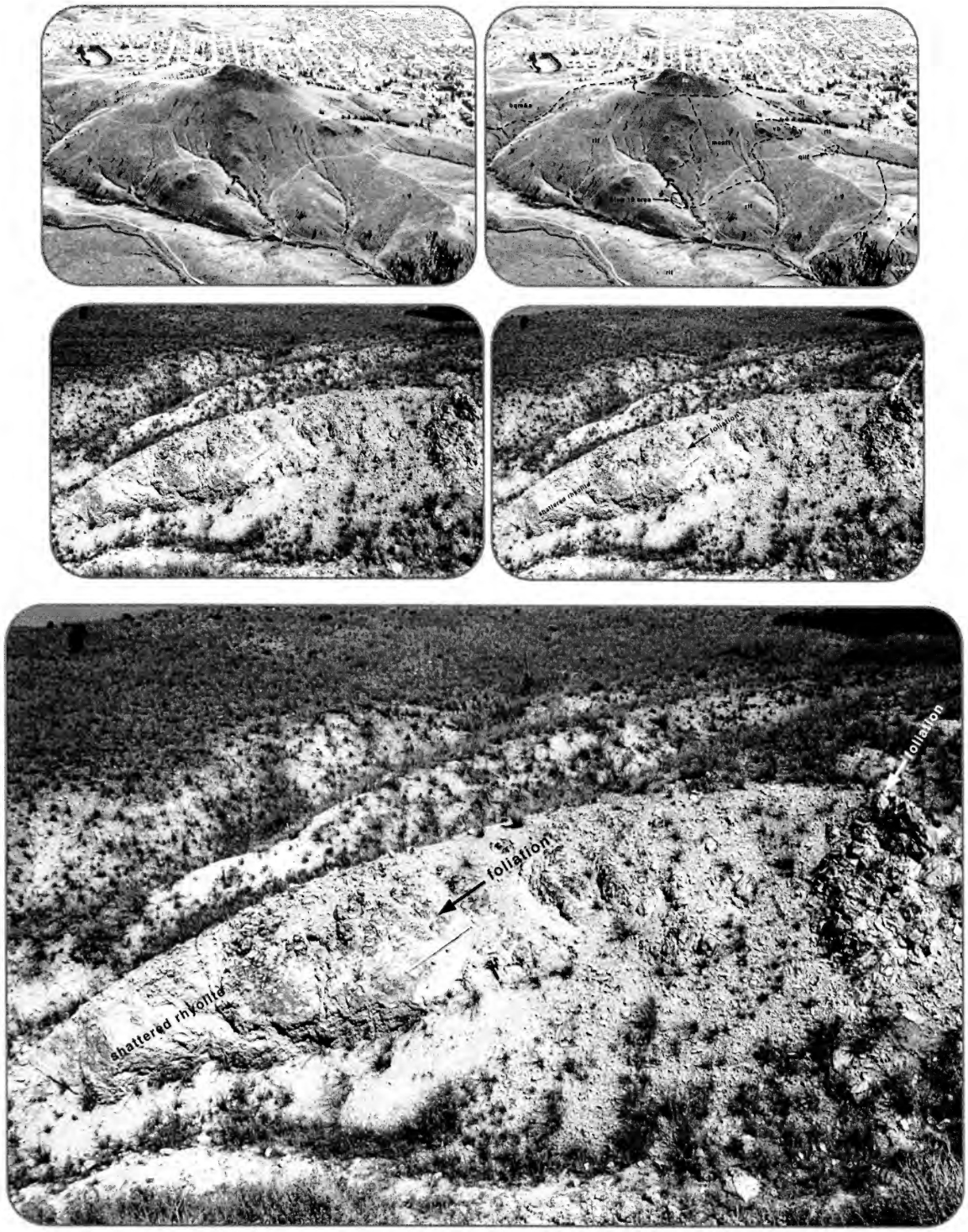
Truncated Foliation



The foliation of the lava behind the hammer butted against the lava under the hammer as chunks of lava jostled within the flow.

Big Butte volcanics Stop 10

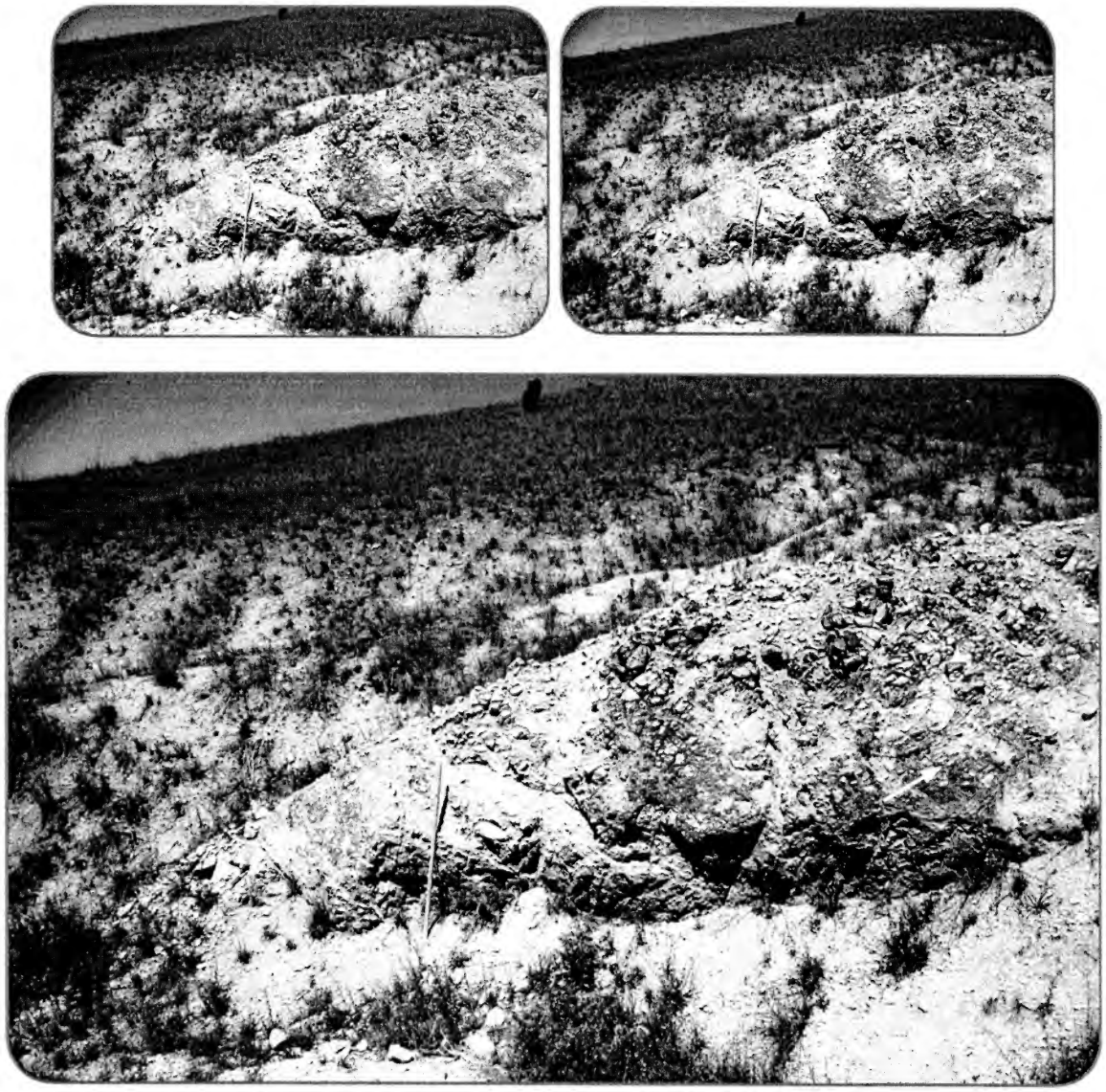
Foliated Rhyolite Grades into Shattered Rhyolite



Shattered rhyolite grades through rhyolite that has rounded clasts aligned along the foliation into foliated rhyolite to the right. The rhyolite may have flowed over a marshy area or a spring whose water flashed to steam and exploded through the rhyolite. If the rhyolite originated as an ash flow, it would have to pond, develop flow banding (foliation), and then brecciate as steam flashed through it, a somewhat unlikely sequence of events. The pogo stick, five feet long, is aligned along the foliation.

Big Butte volcanics Stop 10

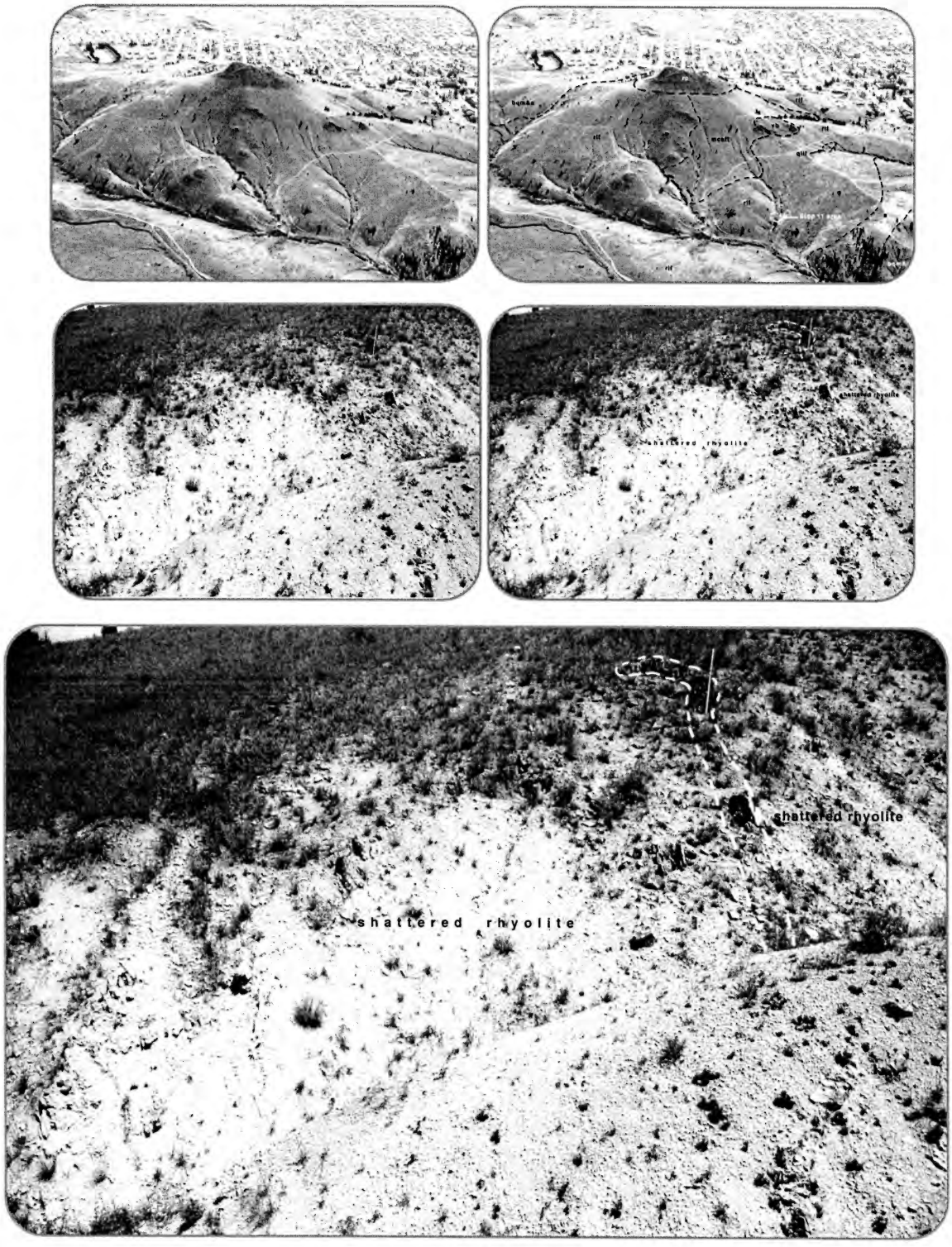
Shattered Rhyolite



This is a closer view of the shattered rhyolite shown toward the left end of the outcrop on the facing page. The white arrow points to rounded clasts of rhyolite aligned along foliation that grades into shattered rhyolite to the left. Another interpretation for the shattered rhyolite is that it may be a carpet breccia that tumbled down the edge of the flow to be overridden by the flow.

Big Butte volcanics Stop 11

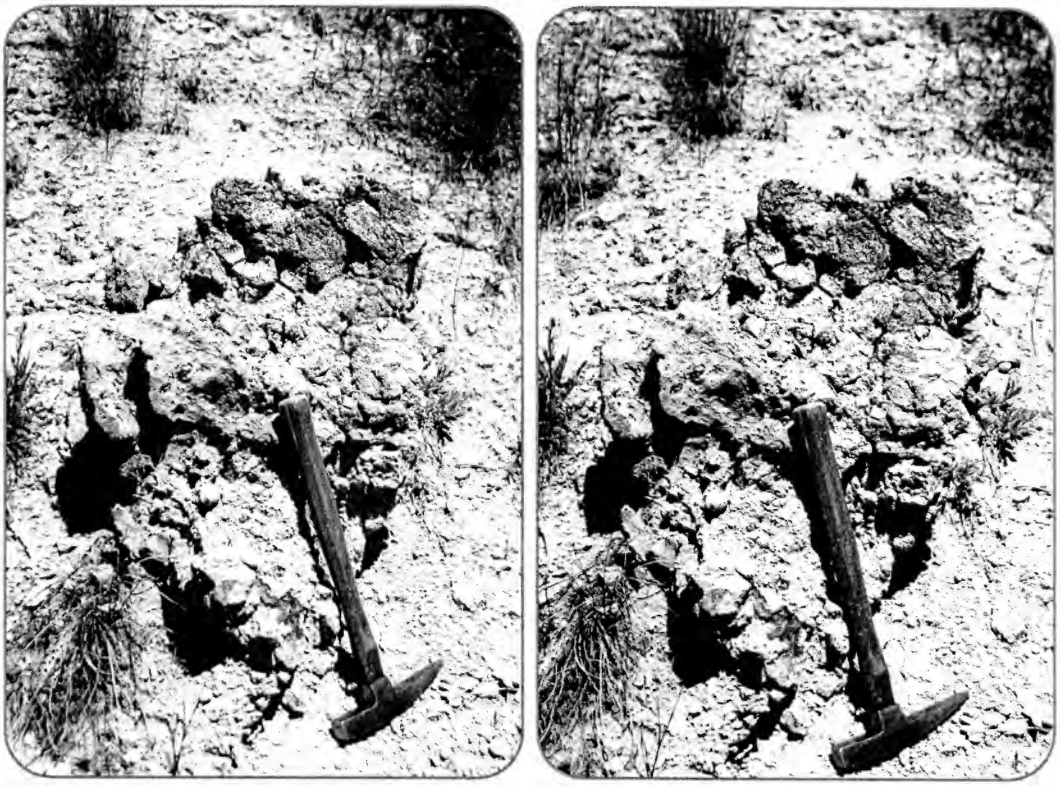
Curved Dike-Like Body in Shattered Rhyolite



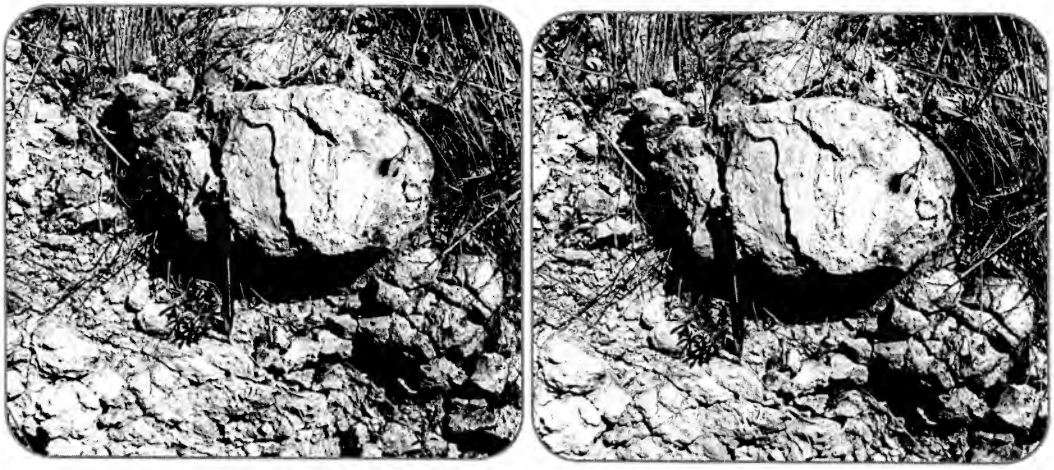
The dashed white line borders a curved dike-like rhyolite body surrounded by shattered rhyolite.

Big Butte volcanics Stop 11

Shattered Rhyolite & Slippage Surfaces



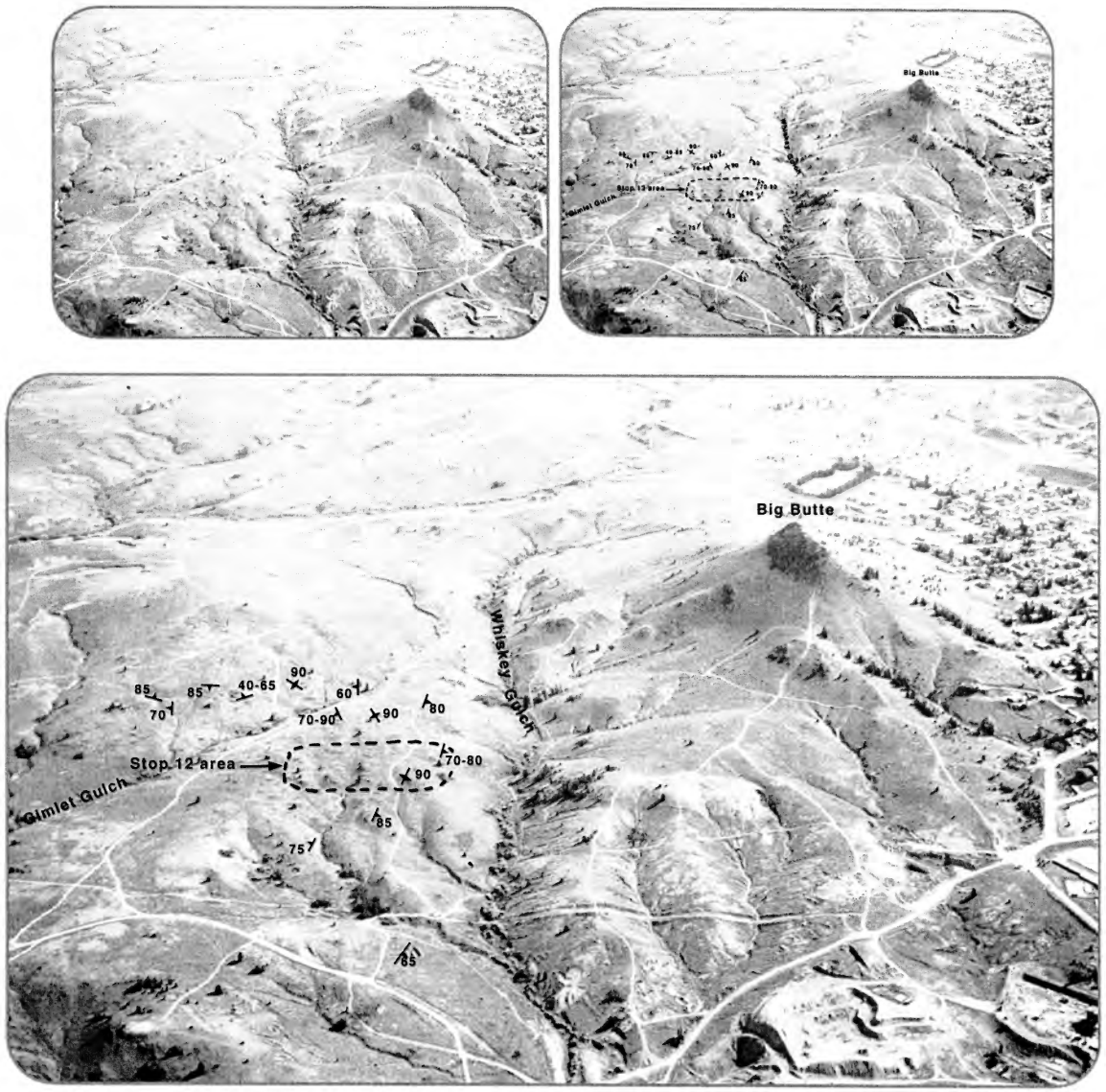
Shattered rhyolite



The smooth surfaces on this chunk of rhyolite are striated slippage surfaces that probably formed as this chunk was squeezed and jostled within the lava flow.

Big Butte volcanics Stop 12

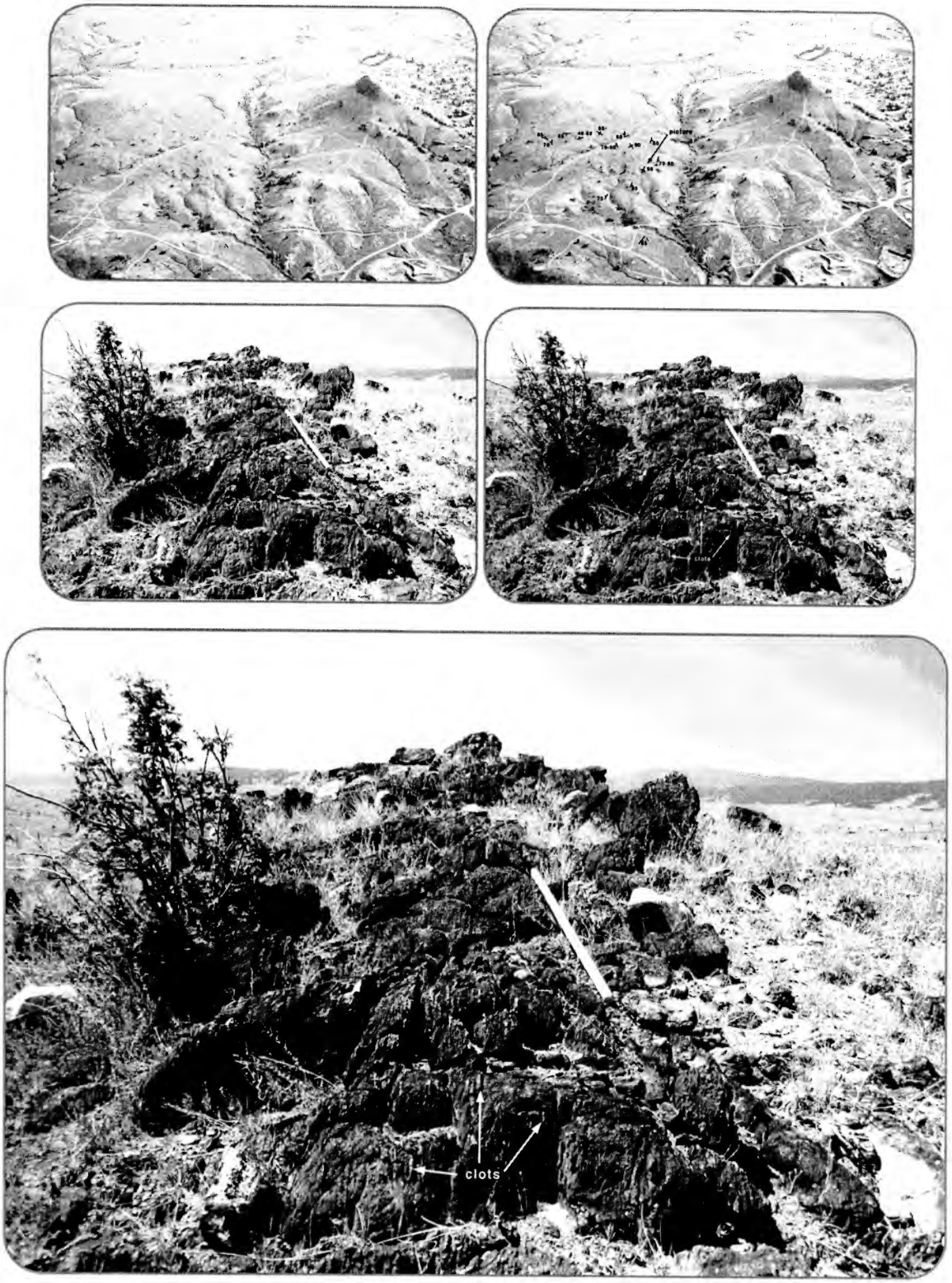
Variable Foliation in Lava Flow



You are looking toward the northeast at rhyolite lava flow outcrops west of Whiskey Gulch. Typically, the flow banding (foliation) dips steeply and is quite variable in strike.

Big Butte volcanics Stop 12

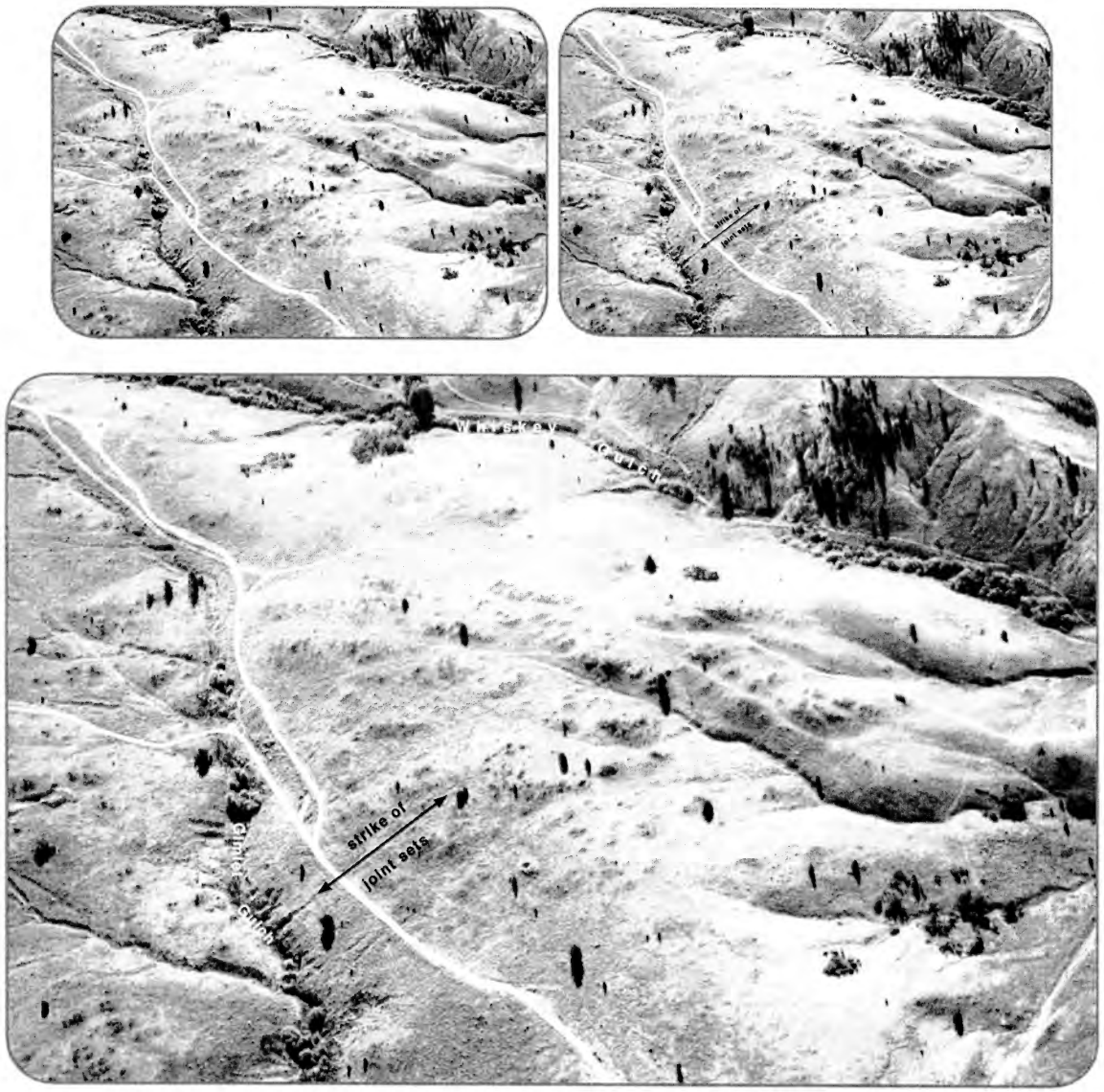
Aligned Clots Define Foliation in Lava Flow



You are looking along strike (S 30 W) at vertical foliation defined by aligned rhyolite clots, a few of which are indicated by arrows.

Big Butte volcanics Stop 12

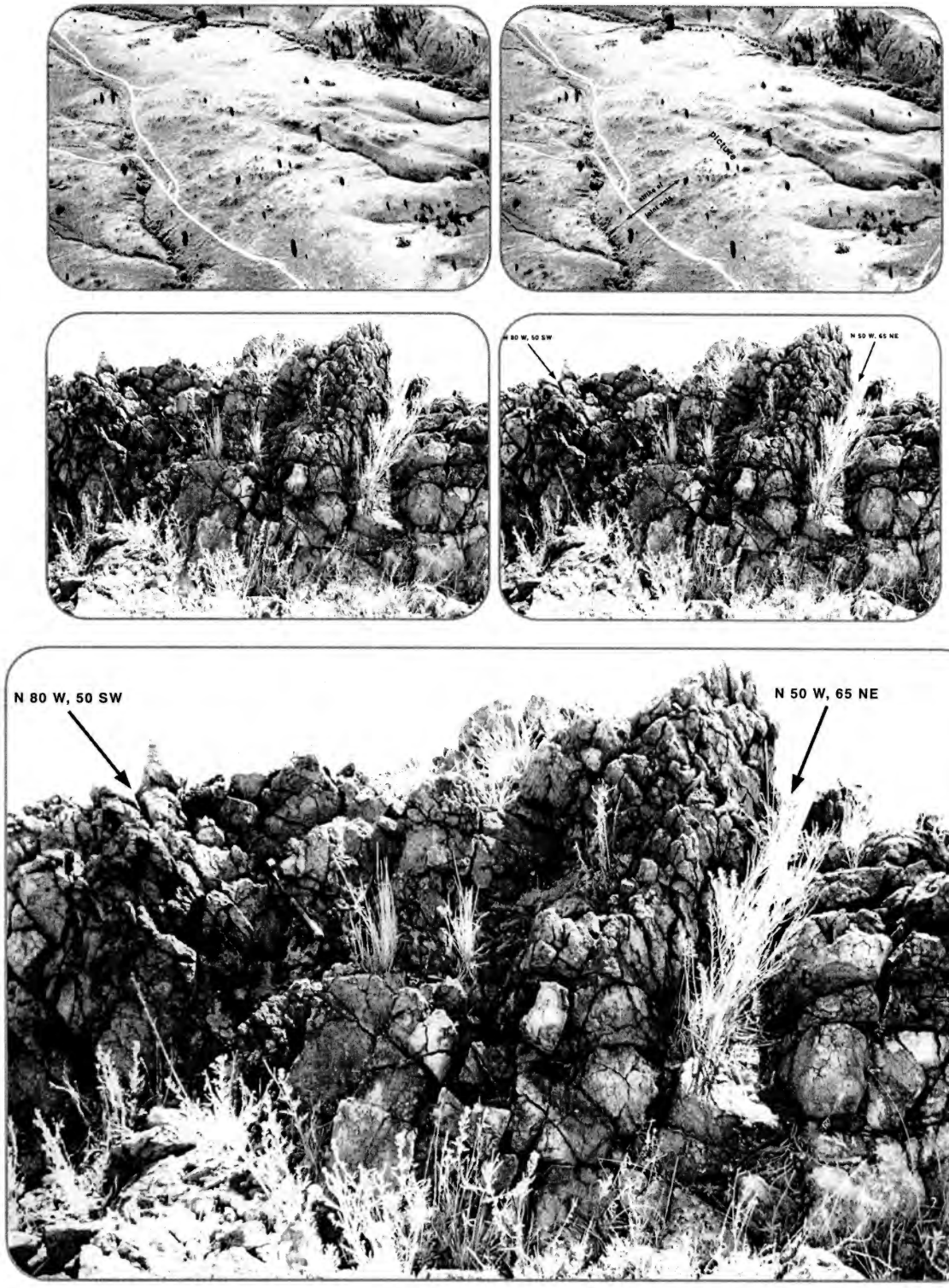
Joint Sets



A prominent set of joints strikes west-northwest and dips about 50 degrees southward. It is cut by a slightly less prominent set that strikes northwest and dips about 65 degrees northeast. The two sets are best developed at this mid level in the rhyolite lava flow, and produce the appearance of a grain through the lava.

Big Butte volcanics Stop 12

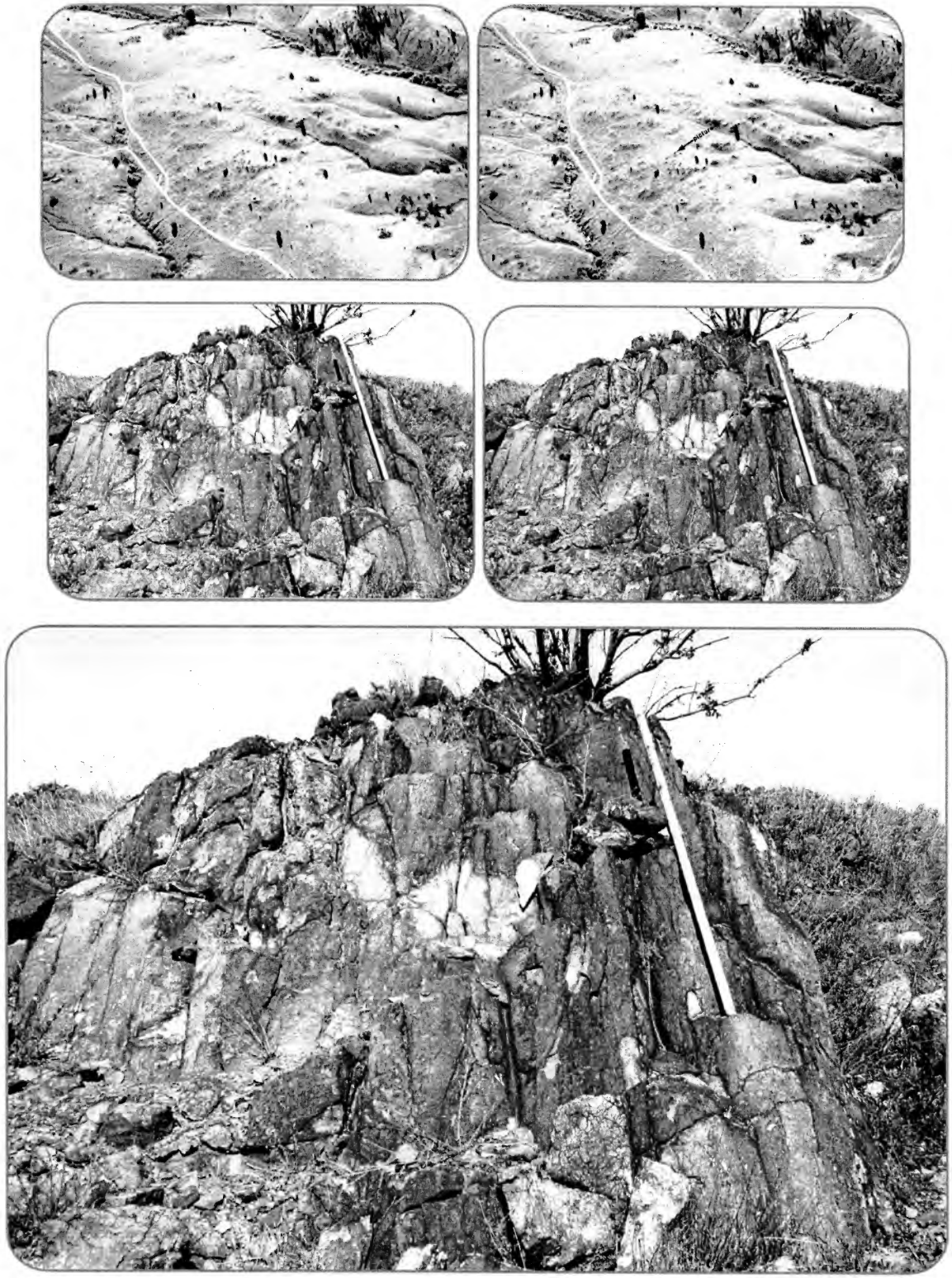
Joint Sets



You are looking southeastward at two sets of crossing joints that produce a grain-like pattern on aerial photos at mid level in the rhyolite lava flow.

Big Butte volcanics Stop 12

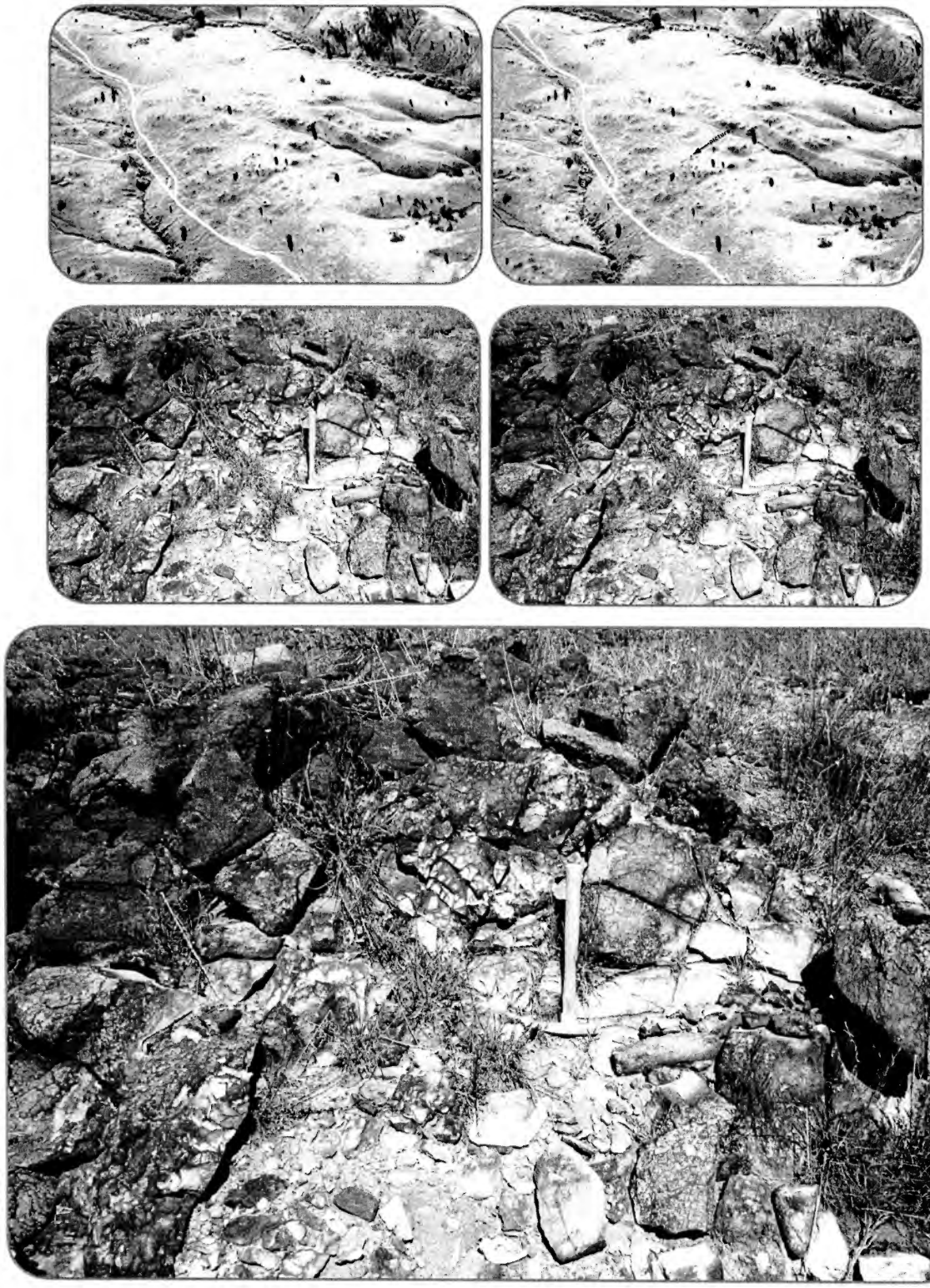
Steeply Inclined Columnar Joints in Lava Flow



This lone set of crude columnar joints plunges 55 degrees S 70 E in the mid level of the rhyolite lava flow.

Big Butte volcanics Stop 12

Angular Breccia



This outcrop, adjacent to the columnar-jointed outcrop shown on the facing page, contains angular fractured chunks of white fine-grained rhyolite.

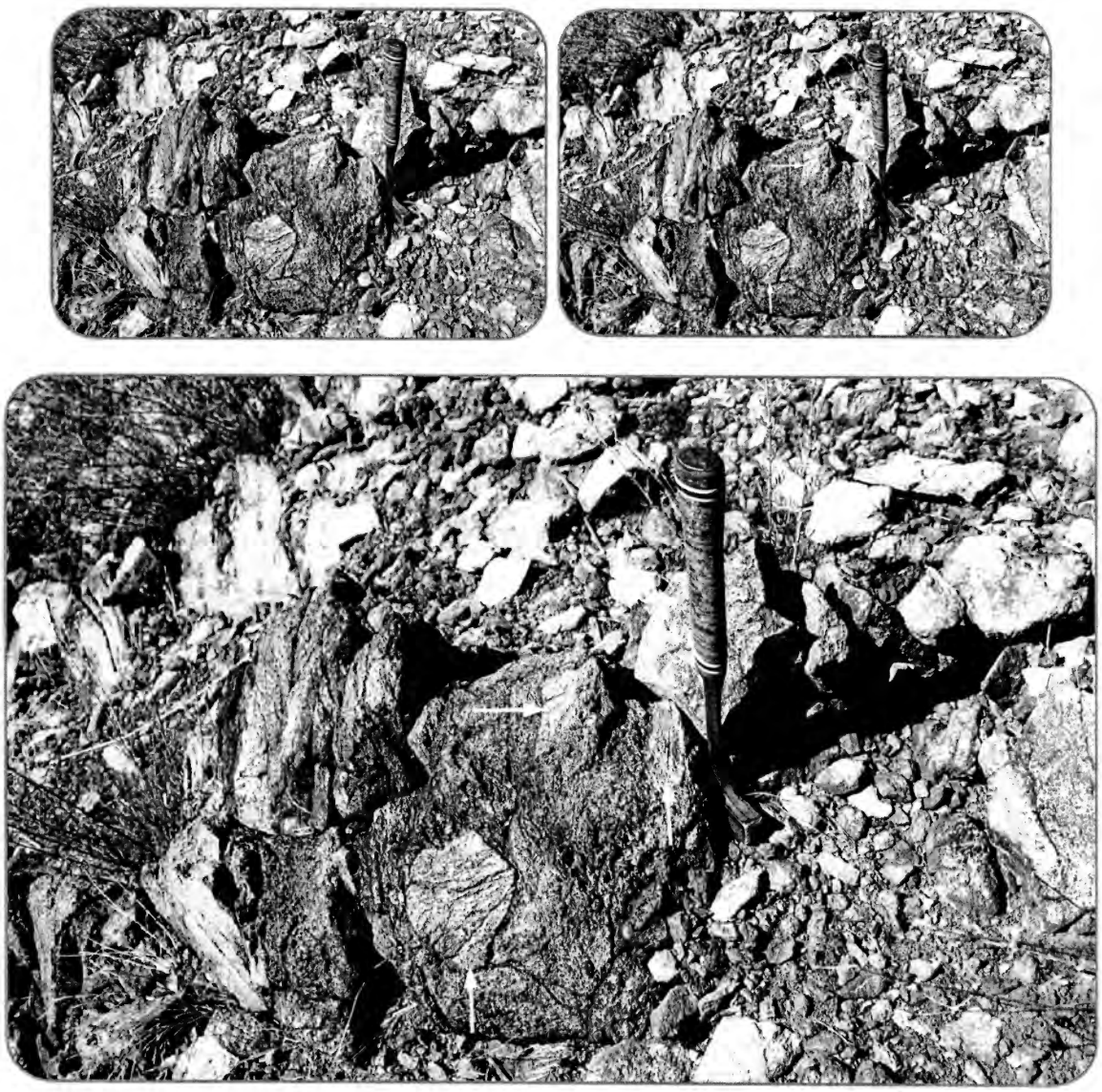
Big Butte volcanics Stop 13

Steeply Dipping Foliation in Lava Flow

You are looking along strike (N 40 E) at foliation that dips 75 degrees northwest. Clasts and lenses of an earlier fine-grained, flow-banded and folded rhyolite lava flow were incorporated along the foliation in the coarse-grained rhyolite lava flow.

Big Butte volcanics Stop 13

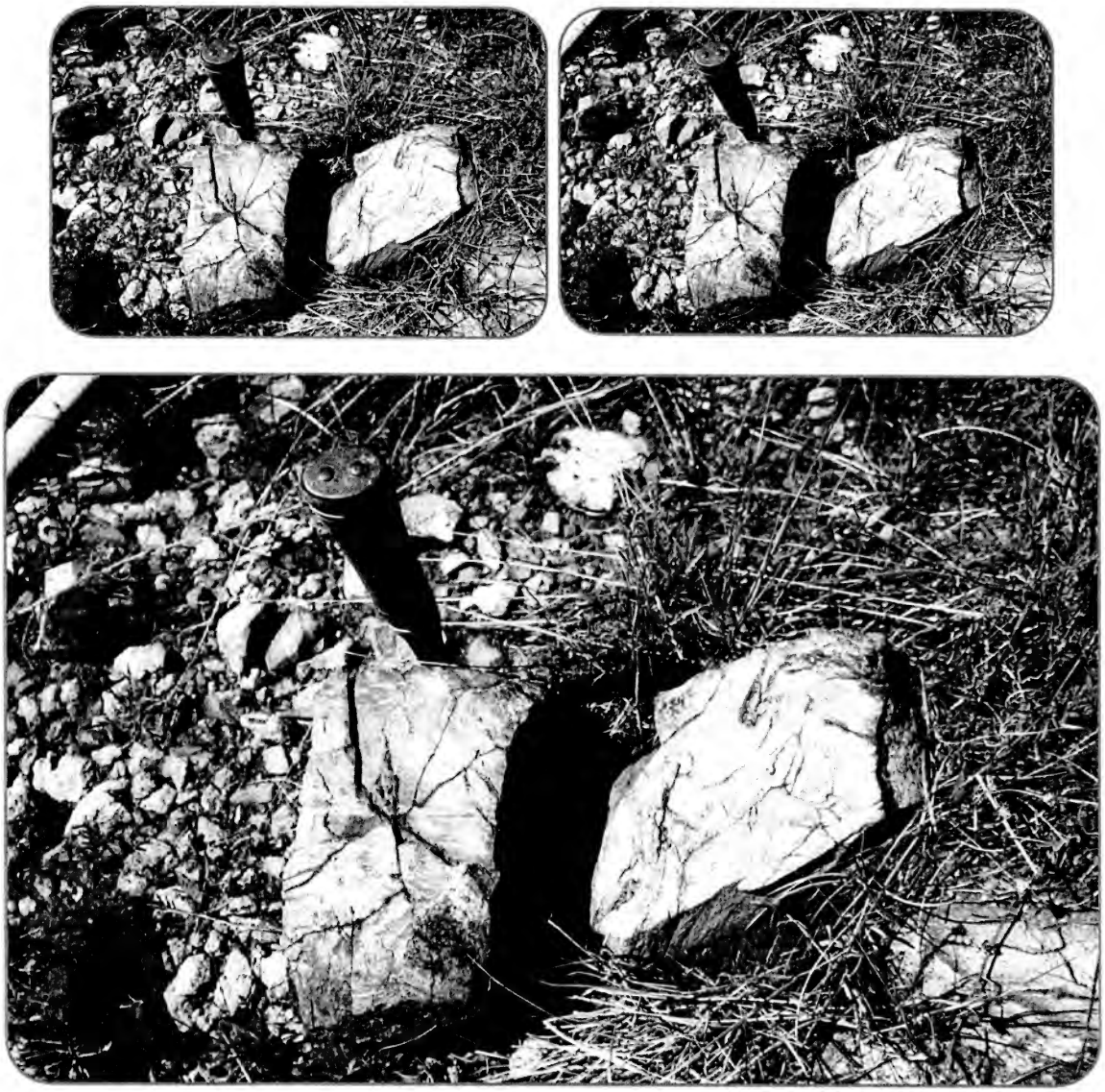
Clasts of Fine-Grained Rhyolite



Arrows point to three variably oriented clasts of fine-grained flow-banded rhyolite picked up by the coarse-grained rhyolite lava flow.

Big Butte volcanics Stop 13

Folded Flow Bands in Fine-Grained Clasts



The foliation is folded in these two chunks of fine-grained rhyolite.

Big Butte volcanics Stop 13

Coarse-Grained Rhyolite Erodes Fine-Grained Clast & Rhyolite Clot

Coarse-grained rhyolite cuts the flow banding of fine-grained rhyolite.

Flow bands in coarse-grained rhyolite kink and flow around an eye-shaped clot of coarse-grained rhyolite.

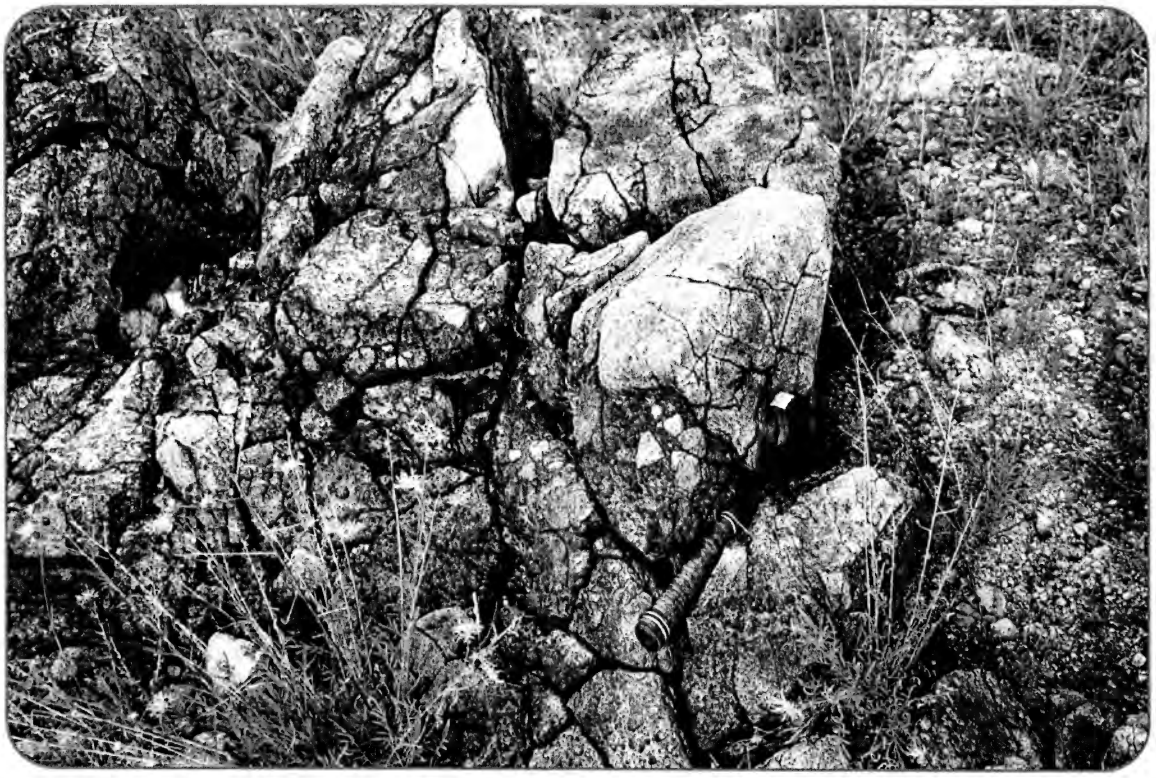
Big Butte volcanics Stop 14

Fractured Clasts in Breccia

Several of the rhyolite clasts were fractured before they were added to this deposit, probably part of a traction-carpet breccia near the base of the lava flow.

Big Butte volcanics Stop 14

Tortoise Shell Fractured Breccia & Photomicrographs

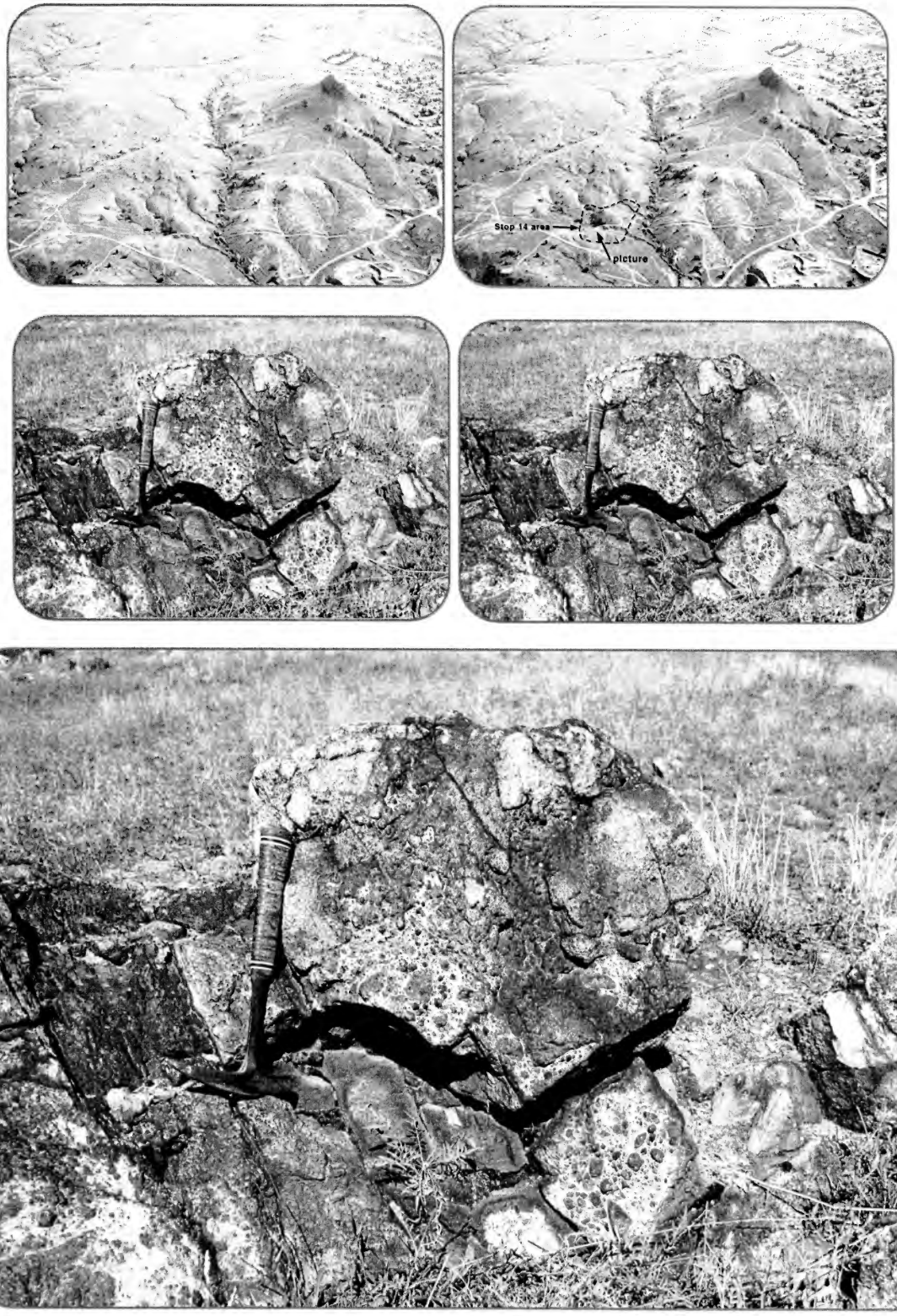


The tortoise shell fracture pattern was produced by contraction as the lava cooled. On two different scales, it occupies individual clasts in the breccia and extends through the breccia, which is interpreted to be a traction-carpet breccia.

Both the fine-grained rhyolite (lower half of photomicrograph) and the coarse-grained rhyolite are made of broken crystals of feldspar, quartz, and biotite embedded in a finely crystalline groundmass. Plane (left) and crossed (right) polarizers, about 50x.

Big Butte volcanics Stop 14

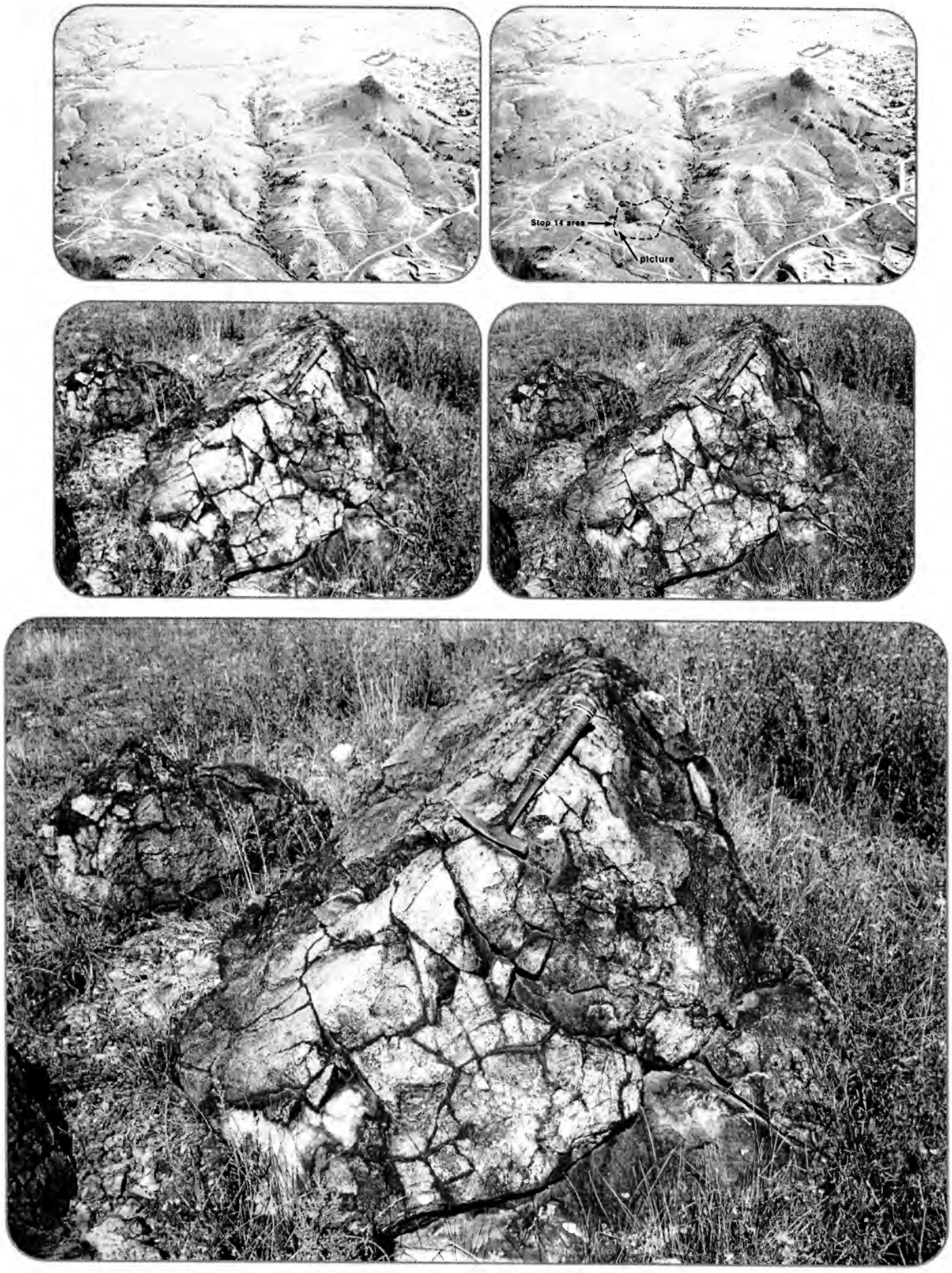
Traction-Carpet Breccia



This breccia is probably part of the traction-carpet breccia near the base of the rhyolite lava flow. It probably formed as broken and ground up chunks and bits of lava cascaded down the edge of the flow to be overridden by the advancing lava.

Big Butte volcanics Stop 14

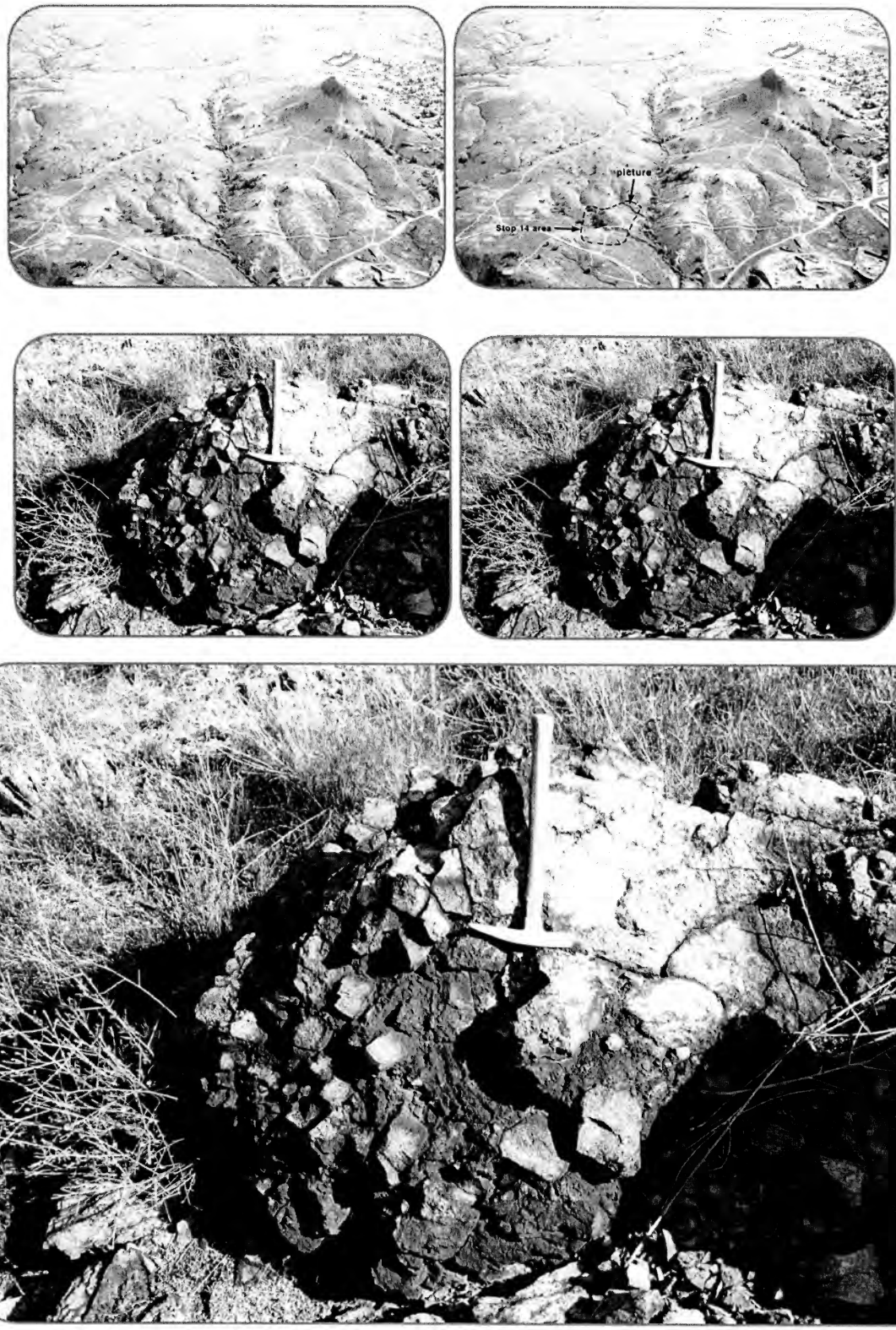
Tortoise-Shell Fractures



Rhyolite near the base of the lava flow fractured in a tortoise-shell pattern as it cooled and shrank.

Big Butte volcanics Stop 14

Angular-Clast Traction-Carpet Breccia

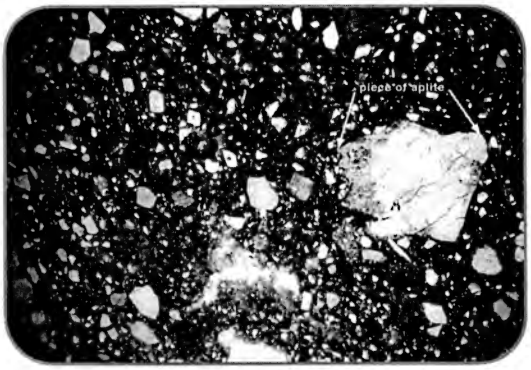


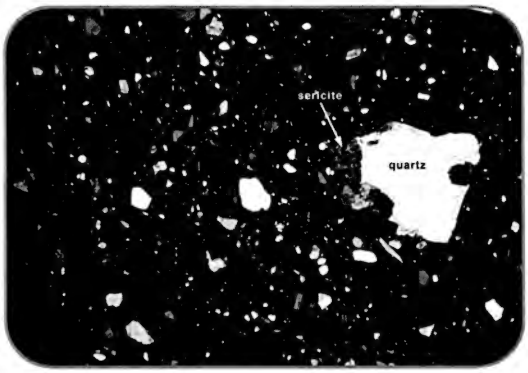
Angular chunks of fine-grained rhyolite are embedded in coarse-grained rhyolite near the base of the rhyolite lava flow.

Big Butte volcanics Stop 14

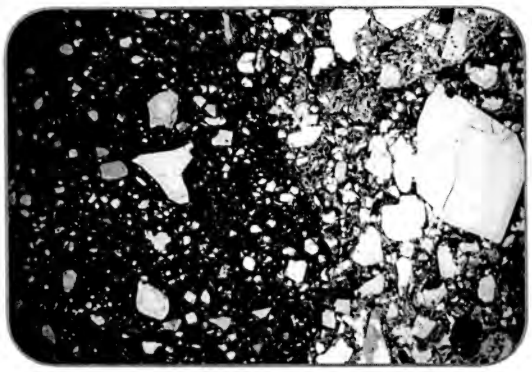
Photomicrographs of Angular-Clast Traction-Carpet Breccia

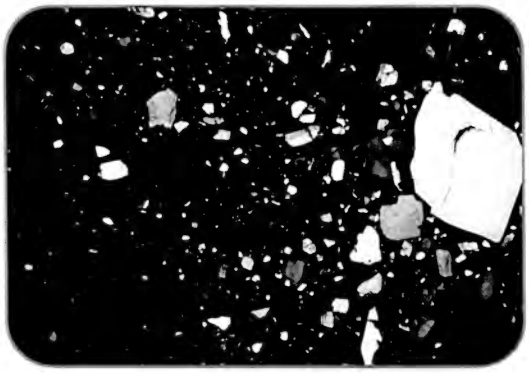
The photomicrographs on this page are of the breccia shown on the facing page.





The breccia is made of crystal fragments. The large fragment is probably a piece of alpite whose feldspar has been altered to sericite. The left image was taken using plane polarized light; the right image was taken using crossed polarizers. Magnification is about 50x.

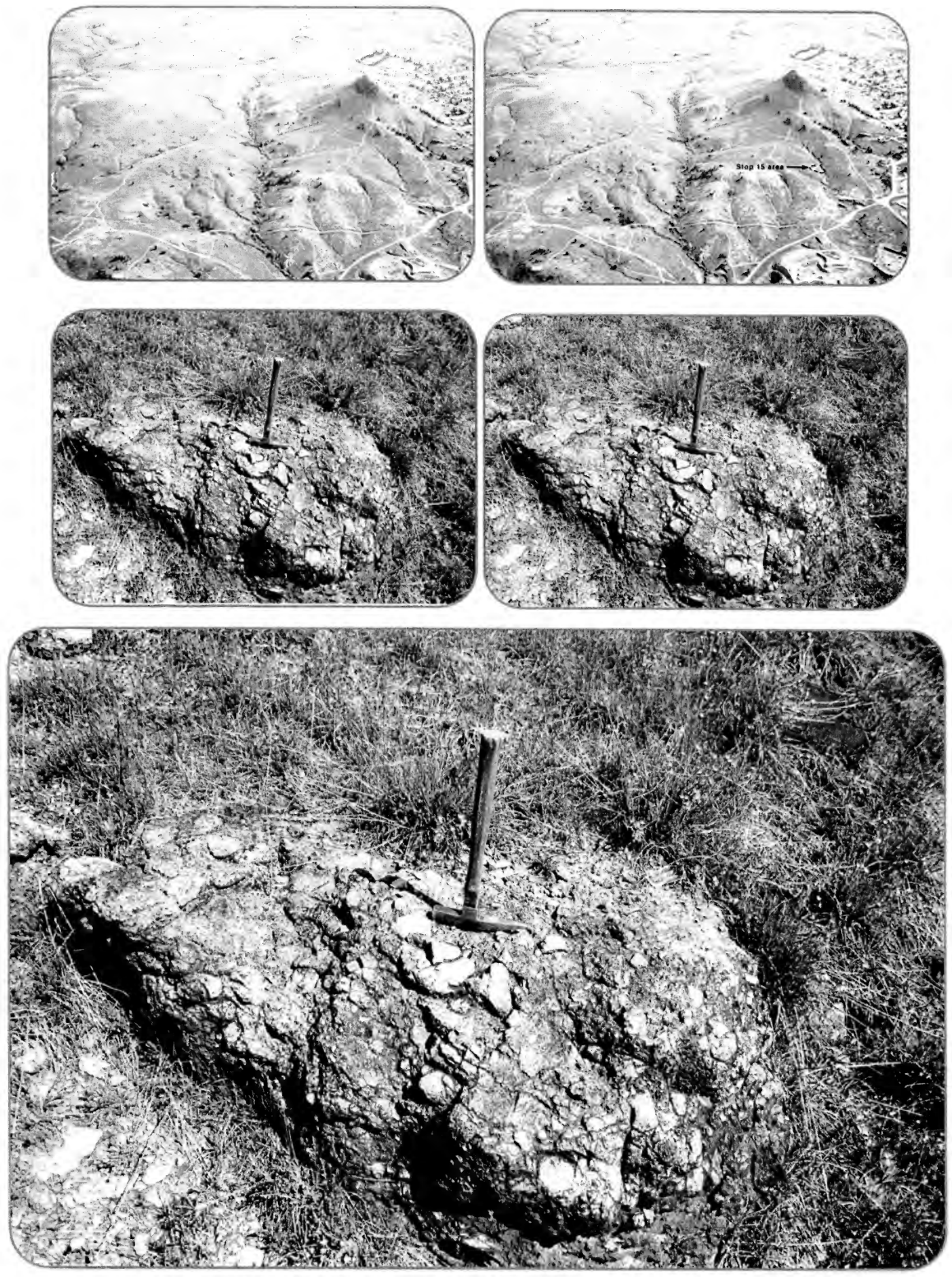




Fine-grained rhyolite on the left has a finer and darker groundmass. It is in contact with coarse-grained rhyolite on the right. Both rhyolites are made of crystal fragments. The largest fragment is a piece of quartz. The left image was taken using plane polarized light; the right image was taken using crossed polarizers. Magnification is about 50x.

Big Butte volcanics Stop 15

Aplite Breccia



Fine aplite forms breccia chunks in coarser aplite.

Notes