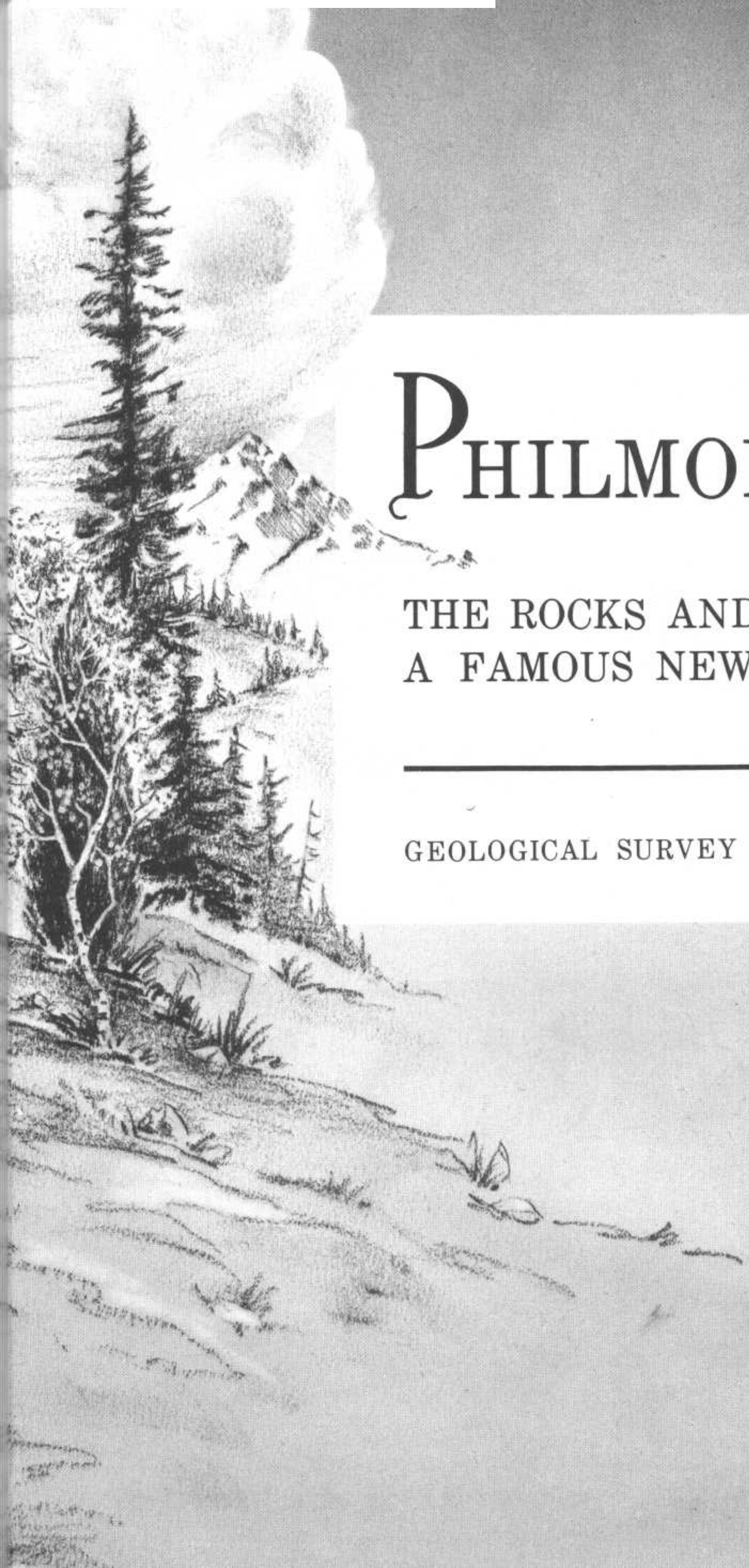


PHILMONT COUNTRY

THE ROCKS AND LANDSCAPE OF A FAMOUS NEW MEXICO RANCH

GEOLOGICAL SURVEY PROFESSIONAL PAPER 505 cold rocks would be expected to cool more quickly and be finer grained than a large mass. If the intruded rocks were almost as hot as the magma, however, even a small amount of magma would cool slowly and end as a coarse-grained rock.

But more than the rate of cooling is involved, for the same small mass may grade in a few inches from fine-grained granodiorite to pegmatite. Understanding begins when we realize that besides being coarser grained than the granodiorite, the pegmatite contains much more water: it is richer in biotite and muscovite, which contain much water, and poorer in feldspar, which contains none. Probably the pegmatite is coarser grained because it crystallized from a part of the magma kept fluid by dissolved water vapor; molecules were able to migrate more easily through it than through the stickier, water-poor parts of the magma, so that larger crystals could grow there during the same time that smaller ones were growing nearby.

Where did the granodiorite magma come from? Granodiorite occurs only in the metamorphic rocks and has the same minerals as the metamorphic rocks, but it differs in texture. A reasonable idea is that the granodiorite represents bands of gneiss that were heated a little more than others, perhaps because they were more deeply buried, and consequently melted enough to flow a short distance and to crystallize with igneous texture. The temperature at which this might happen would vary with the weight of overlying rock and the amount of free water in the gneiss. Laboratory experiments suggest that a granodiorite magma might form at temperatures as low as 1000°F under 10 miles or more of rock cover.

Yellow and gray quartz sandstone

Many prominent light-colored bare ridges in the mountains are made not of dacite porphyry but of sandstone. From a distance it may be hard to tell which is which, but there is no doubt whatever at the outcrop.

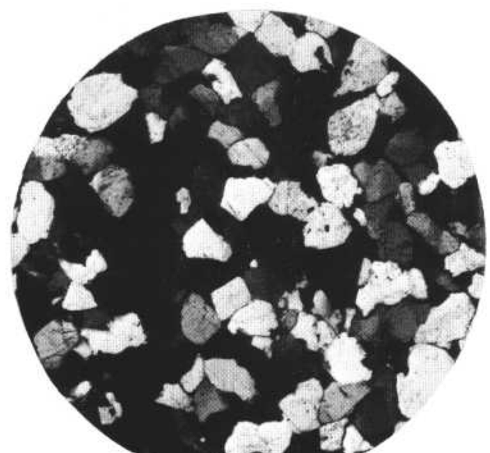
At the eastern mountain front, the first bare ridge that is not dacite porphyry is pale-yellow or gray sandstone, as in the upper canyon of Cimarron Creek where it opens into Ute Valley (fig. 65*A*). Good exposures can also be found farther back in the mountains, especially in the wilderness country at the west boundary of the Scout Ranch, west of Cimarroncito Peak, and north of Comanche Peak. One of the best places to see this rock easily is on the trail along South Fork Urraca Creek (fig. 66). The rock is in beds many feet thick, but weathers into thin plates or slabs. In some places the sandstone is crossbedded like the sandstone of the northern benchlands (see fig. 37).

This sandstone is made almost entirely of quartz; and the grains, many of which have a frosted look, are somewhat rounded, rather uniform in size, and tightly cemented (fig. 65*C*). To distinguish it from sandstone rich in other minerals as well as quartz, we will refer to it as quartz sandstone. The yellow variety is mainly cemented with silica; the gray, with calcite and clay. The rock is broken by irregular fractures which are healed with chalky white calcite or clear quartz. In photographs, the rock looks rather like the quartzite of the mountain country (compare fig. 60), but there is no mistaking the rocks themselves: the sandstone, though hard, breaks around the grains and therefore has lumpy dull surfaces; the quartzite breaks across the grains and has smooth, shiny surfaces.

Most of this sandstone was probably laid down by ocean currents on beaches, as was the gray sandstone of the benchlands, which it somewhat resembles; but the quartz sandstone must have been worked over a great deal more. The crossbedded parts may, however, have been laid down by beach winds rather than by beach waters: they may be fossil dunes. Their crossbedding and texture are like those of existing dunes that are piled up by prevailing winds where there is an abundant supply of sand unprotected by soil and vegetation (fig. 67). Dunes are usually thought of as features of deserts, either far inland, as in Death Valley in California, or along dry hot coasts, as in the Sahara. But there are many dune fields in cool wet climates along open coasts, as on the shores of Lake Michigan or of the Baltic Sea. If most of the quartz sandstone is an ocean-beach deposit, then the crossbedded part no doubt represents coastal dunes. Fossils might help confirm this and also help decide whether the windy beaches were on a hot dry coast or on a cold wet coast, but no fossils have been found in these rocks.

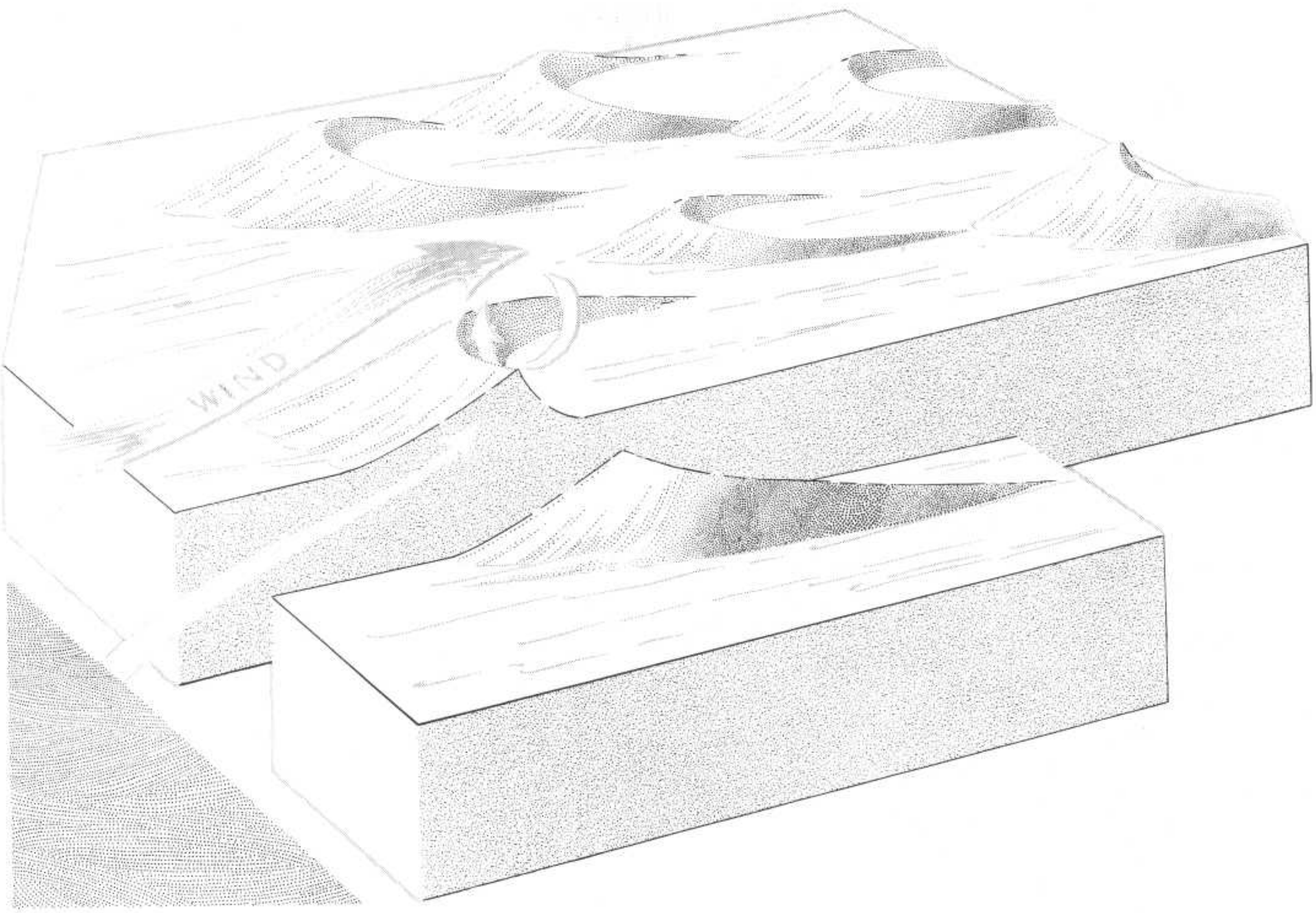
Red sandstone and conglomerate

Low ledges of dark-red or reddish-brown coarse-grained sandstone and conglomerate flank many parts of the mountain core. The only large body of such rocks is on Rayado Creek, where they underlie almost a square mile of canyon land southeast of Rayado Peak. There are good but small exposures along Cimarroncito Creek (figs. 68, 69) and in the northeast slopes of Bear Mountain.



QUARTZ SANDSTONE (Dakota Sandstone)—relic of ancient beaches. A, Outcrop at mouth of upper canyon of Cimarron Creek. B, Piece of sandstone. C, Slice of sandstone, magnified 24 times. Doubly polarized light. All the grains are quartz. (Fig. 65)

QUARTZ SANDSTONE (Entrada Sandstone) on the trail along South Fork Urraca Creek. (Fig. 66)



SAND DUNES: what they are like, inside and out. Neat crescent shapes like these are formed only where sand is plentiful and the wind is from one direction. Most real dunes are much less regular. (Fig. 67)

The sandstone (fig. 70*A*) is made up of large to small poorly rounded grains of quartz, feldspar, hornblende, and biotite, cemented by iron-stained clay and silica.

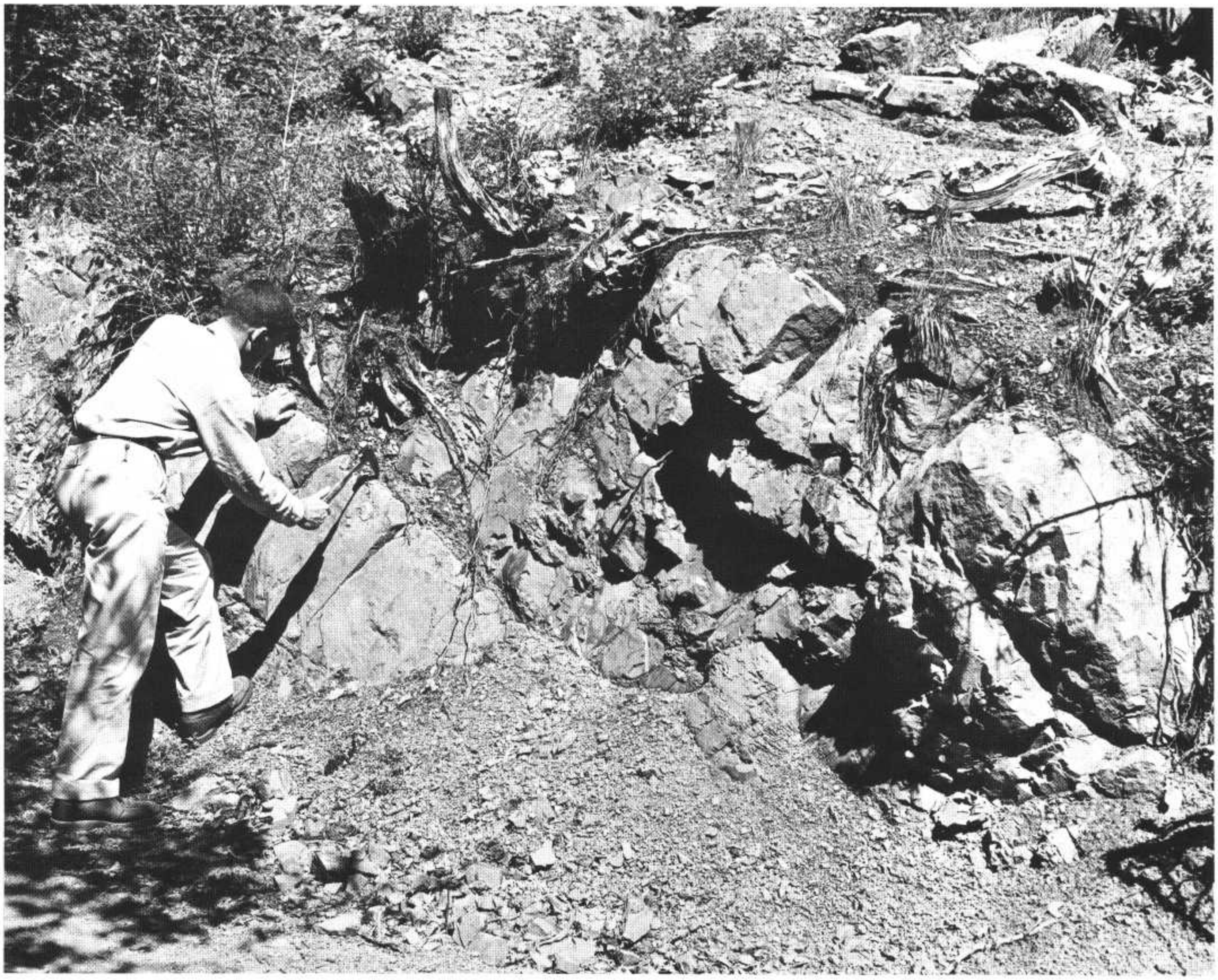
The conglomerate (fig. 70*B*) contains a lot of the same sand, packed between poorly rounded pebbles and cobbles of gneiss, schist, and pink granodiorite.

Along with the red rocks are a few beds of gray sandstone and conglomerate, like the red ones except for color.

These red and gray rocks differ only in color from the yellow sandstone and conglomerate of the benchlands and were no doubt formed the same way—in the channels of overloaded streams. The coarseness, angularity, and poor sorting of the particles indicate that the source areas were not very far away: tens of miles perhaps, but not hundreds. The streams that carried the sediments flowed off an earlier generation of nearby mountains that had a core of rocks like that of the Cimarron Range—gneiss, schist, granodiorite.

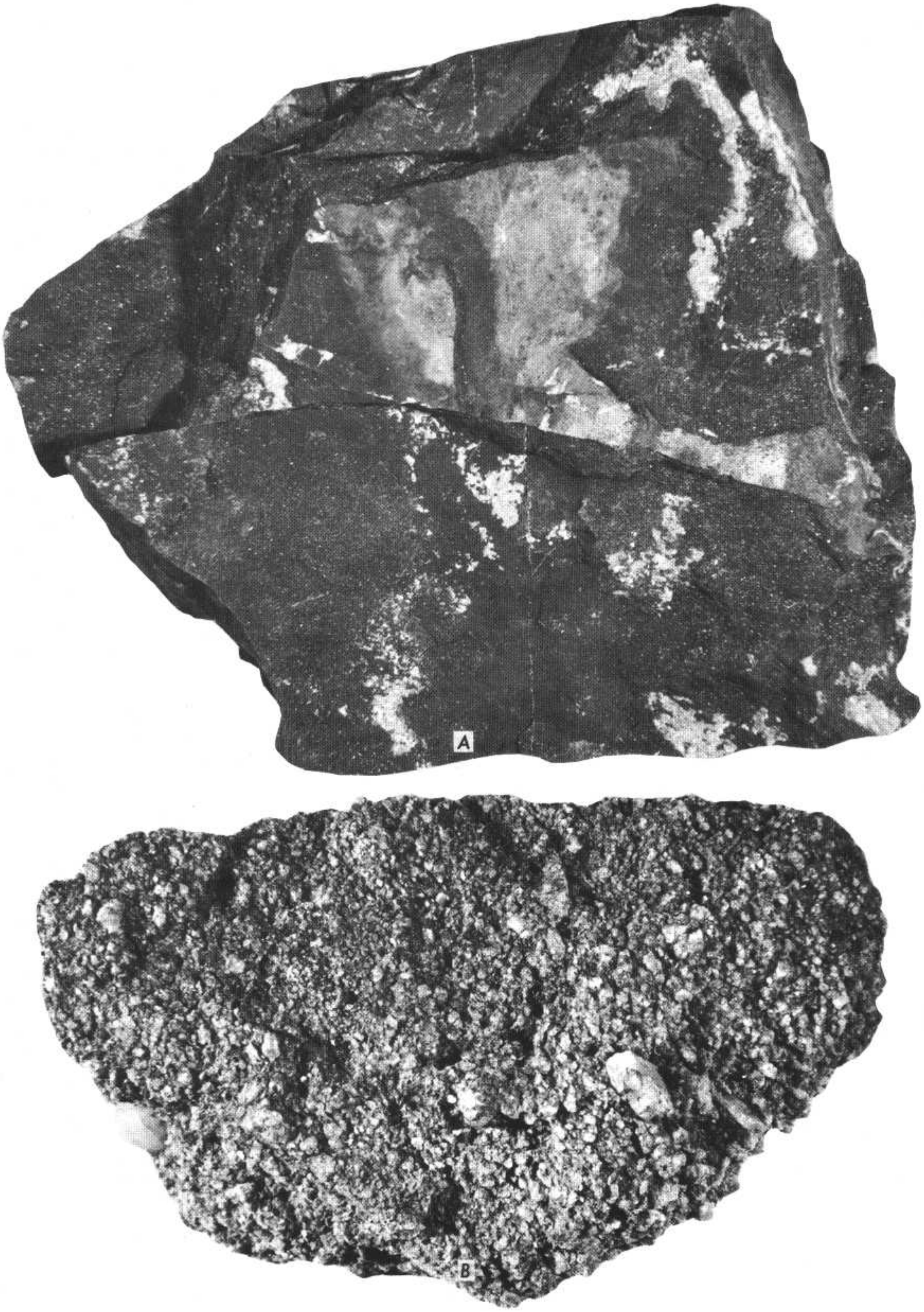
The red color is mainly that of iron hydroxide, often called limonite, which results from the rusting of iron-bearing minerals, mostly magnetite. The iron hydroxide is a thin coating on grains of several minerals, and some is also mixed with the cement. In this way it colors intensely, though it is probably less than 1 percent of the total rock. A little of the redness is from pink feldspar.

Red rocks of this sort are known throughout the Sangre de Cristo Mountains. They crop out on mountain peaks and in deep canyons and have been cut far beneath the surface by mine workings and by drill holes. Probably they are red not because of modern weathering but because they were stained red when deposited. The redness most likely comes from ancient soils that were eroded by the streams and mixed with fragments from other rocks; dark-red soils that could be the source for future red rocks are forming today in many damp



RED SANDSTONE (Sangre de Cristo Formation) deposited by long-vanished streams. Outcrop on Cimarroncito Creek. (Fig. 68)

STREAM-LAID RED CONGLOMERATE (Sangre de Cristo Formation). Outcrop on Cimarroncito Creek. (Fig. 69)



A CLOSER LOOK at red sandstone (A) and red conglomerate (B) from outcrops on Cimarroncito Creek. The bright specks are flakes of mica. Natural size. (Fig. 70) lowlands of the world. The red color suggests, therefore, that the land from which these rocks were worn was deeply weathered and was under conditions of landscape or climate in some way different from those under which the otherwise similar but non-red stream-made deposits of the benchlands were laid down. Further clues to these conditions come from fossils in red shale interlayered with these rocks and discussed next.

Red shale and black shale

Red shale and black shale lie beneath much of the mountain front but are easily weathered to soil, so that outcrops are scarce. The black shale is the same as that beneath the plains, and no more need be said about it.

Good but small exposures of red shale can be seen along a few of the main trails, such as near the junction of South and Middle Forks Cimarroncito Creek (fig. 71*A*) and on South Fork Urraca Creek near the foot trail to Fowler Pass. Along with the red shale are a few beds having other colors—mostly brown, green, or gray.

Like the black shale, the red shale is dried, hardened, and compressed mud. The red mud, however, did not settle out on the sea floor but on the flood plains of sluggish streams. The red shale, unlike the black marine shale, has no animal fossils but does have scattered remains of several species of extinct plants (figs. 71*B*, *C*) including the remarkable seed-fern (fig. 71*D*). Unlike living ferns, this fern reproduced from seeds, not by spores. The red shale has much more sand-size material—mainly quartz and rock chips—and far less clay and organic fragments than does the black shale. In fact, it is a fine-grained version of the streamlaid red sandstones that are interlayered with it.

The plant remains tell a little about the conditions that prevailed when the red rocks were forming. Similar living plant communities do not normally grow at anything like the present altitude or climate of Philmont. Instead, they flourish in damp, warm to cool climates within a few thousand feet of sea level.

Limestone conglomerate

A rare and interesting rock at Philmont is a dark-gray conglomerate made of pebble-size pieces of limestone. This rock, in beds no more than a few feet thick, is only found close to outcrops of red sandstone and red shale (fig. 72). The pebbles are mostly biscuit shaped and have rounded edges, but some are rather sharp edged. They are packed tightly together and are cemented by a mixture of sand and clay.

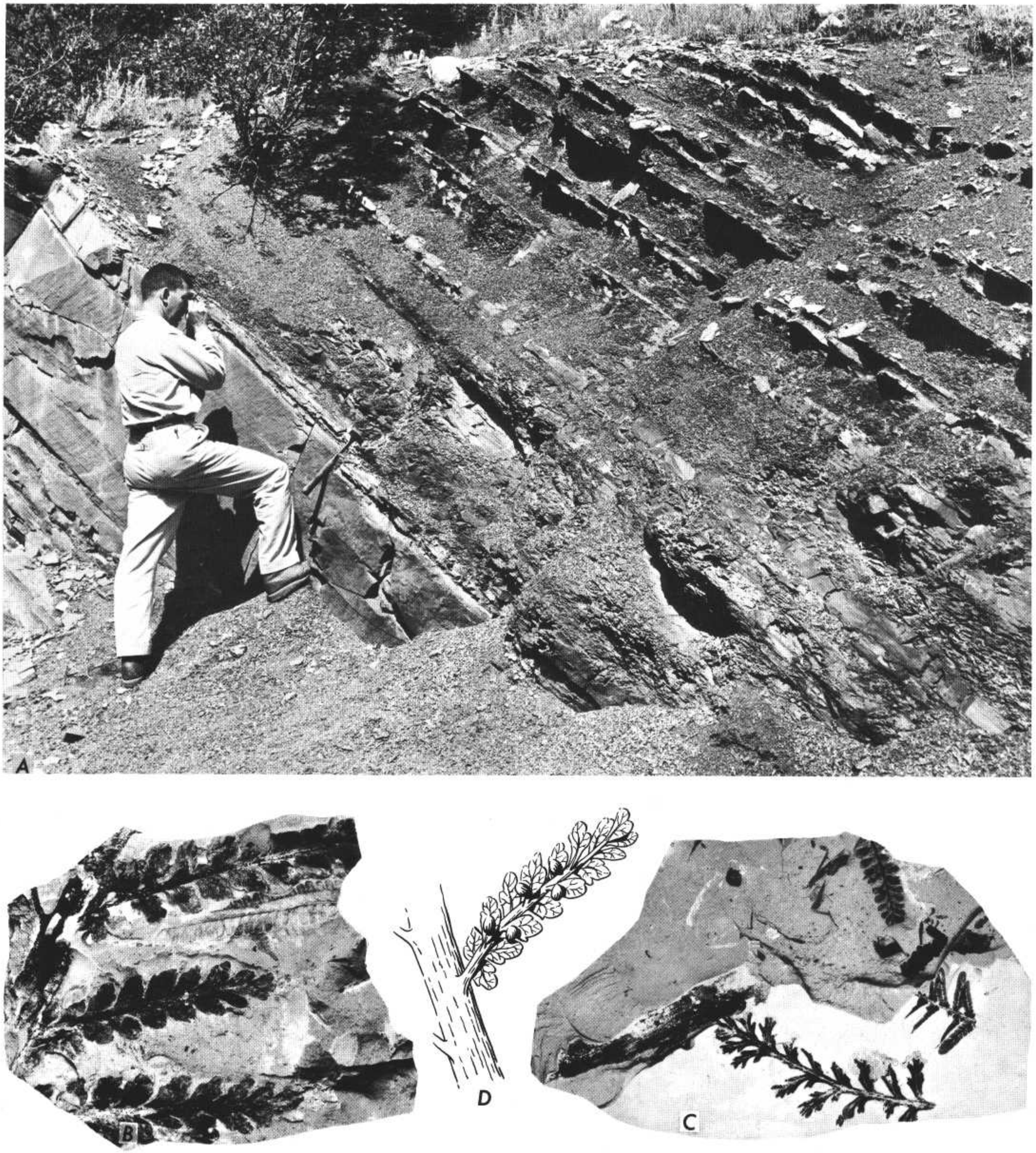
Because the rocks above and below are streamlaid, it seems likely that these thin layers are in some way related to streams. But streams today, even those flowing over limestone that has a pebbly texture to start with, are not depositing layers of limestone pebbles. Because limestone is both soft and fairly soluble, pebble-size fragments do not last very long in streams: they disintegrate very rapidly from chunks to mud. Furthermore, to get a bed of practically pure limestone pebbles means that there must be thick limestone upstream, but there are no suitable sources of limestone nearby; what little limestone is known in the region did not yet exist when the limestone conglomerate was forming.

Very likely, then, the limestone conglomerate is not an ordinary transported sediment. Perhaps the pebbles were formed about where they are in a shallow lake on a broad flood plain. They may have begun on the lake floor as chemical precipitates that dried, cracked into angular bits, and were partly rounded and redeposited by current or storm waves—this sort of almost simultaneous deposition, reworking, and redeposition has been observed in desert lakes. Or the pebbles may be fossils that have biscuit shapes, for certain algae living in modern lakes and in parts of the sea secrete just such masses.

Basalt

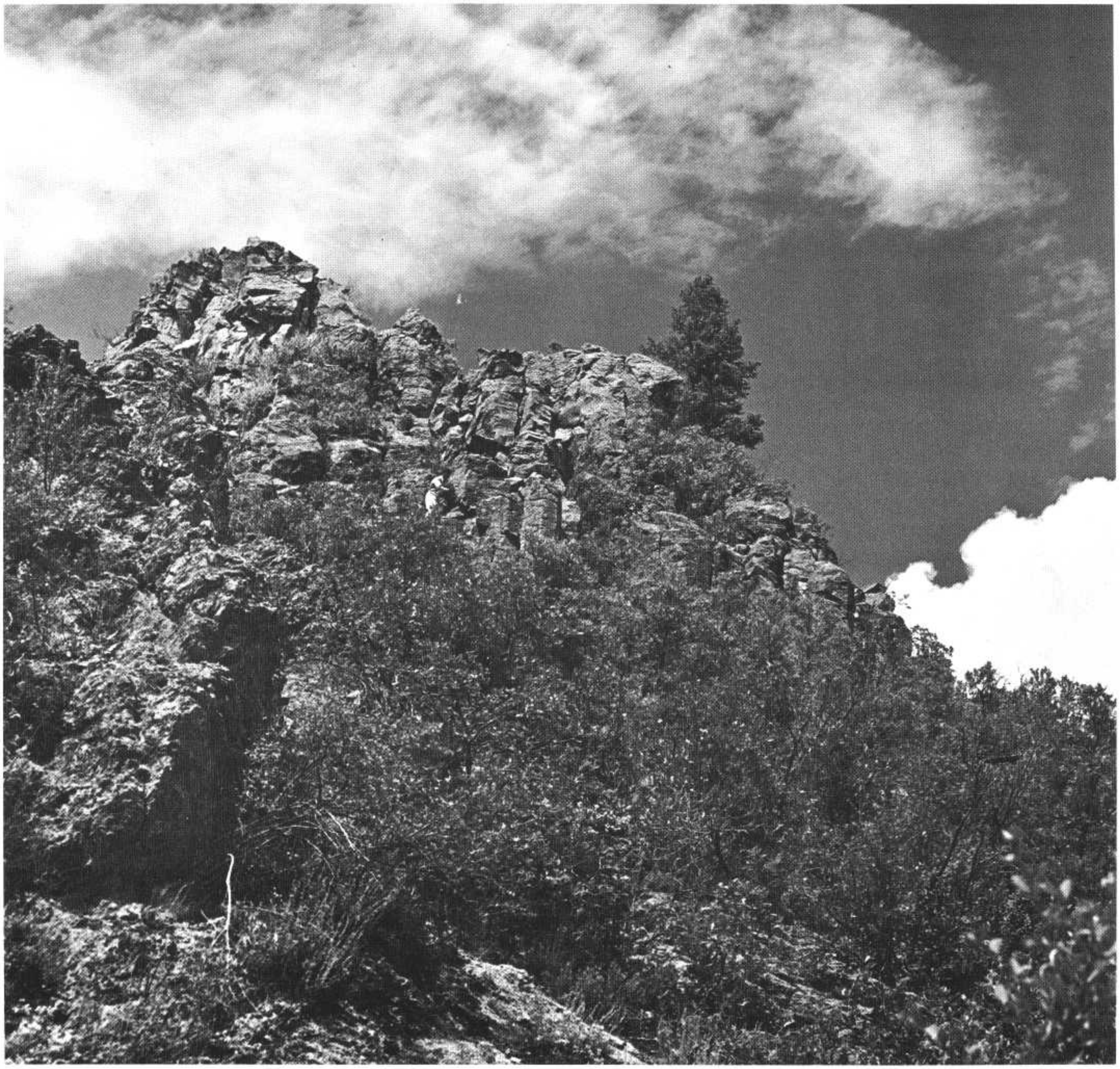
A few small patches of dark basalt cap ridges and peaks at the south edge of the mountain country, near the edge of the basalt-capped Ocaté Mesa. The easiest of these to reach is on the hill above Rayado Base Camp (fig. 73). Another, larger mass makes a little bench at the canyon rim across Rayado Creek from the camp. The largest, but least accessible, of the basalt patches caps Crater Peak and Rayado Peak. Covered by trees and brush, this cap looks very different from the cap on Urraca and Fowler Mesas but is really part of the very same lava flow, cut through by streams.

Most of the basalt is in every way like that on the Ocaté Mesa. On the south side of Crater Peak, however, are a few thin layers of bright-red basalt and of nearly white basalt that look very much like the quartz-rich lava called rhyolite. Probably these brightly colored layers were originally no different from ordinary dark-gray or green basalt but were attacked by the hot gases, mainly steam, that usually accompany volcanic activity. The gases oxidized the green ferrous iron in the basalt to red ferric iron, to make the red variety, and went even farther to make the white variety by dissolving and removing much of the iron and altering the original glass and feldspar to earthy clay minerals.



RED SHALE (Dockum Group) laid down on the flood plain of an extinct river. A, Outcrop near the junction of South and Middle Forks Cimarroncito Creek. The thin beds are shale; the thick beds are red sandstone. B and C, Imprints of extinct plants in red shale. D, Drawing of fronds and seed pods of an extinct seed-fern from red shale. Living ferns do not have seeds, but reproduce by spores. (Fig. 71)

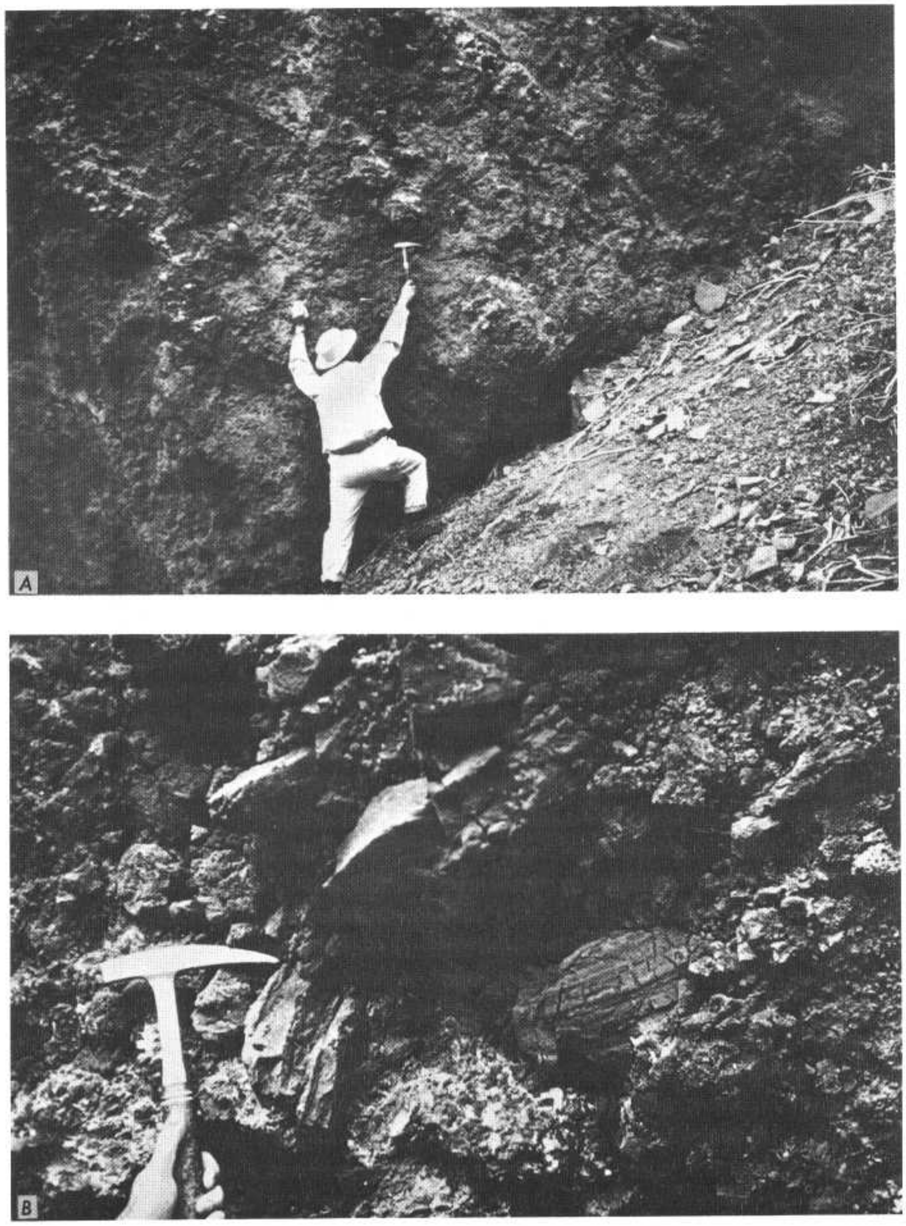
LIMESTONE-PEBBLE CONGLOMERATE, South Fork Urraca Creek. Interlayered with stream-laid rocks, it was probably deposited on land (Fig. 72)



REMNANT OF BASALT LAVA FLOW on hill above Rayado Base Camp. (Fig. 73)

Red bomb beds

Between some of the layers of brightly colored altered basalt lava on the south side of Crater Peak are a few thick stubby beds of red scaly volcanic bombs. Figure 74 shows both a bomb layer and a close-up view of some typical bombs. These bombs were not made by simple outflow of liquid lava. Rather, they are cooled masses of lava that, while still hot enough to flow, were hurled high in the air during especially violent eruptions. During flight they rotated and spun out into bomblike shapes. Meeting cold air, their skins chilled quickly to a breadlike crust, preserving the projectile forms. Large bombs like these are not thrown very far from a vent; so we can be sure that Crater Peak is well named, even though it does not have the cone shape we might expect of a volcanic mountain. During flight the bombs may have begun to oxidize, making them red; but they probably were not in the air long enough for the process to go very far, and it was very likely completed on the ground by hot gases rising through and around them from below. The bombs are so much altered that it is hard to say what kind of rock they were to begin with. The only minerals we have identified in them are shapeless bits of iron hydroxides and clays and rounded blobs of quartz.



RED VOLCANIC BOMBS from the flank of Crater Peak. A, Bomb layer. B, Close-up of typical bombs. Hurled in the air as red-hot blobs of still-liquid basalt lava, they spun into bomb shapes and froze in the air, some with crusts like that of bread. (Fig. 74)

Pepper-and-salt diorite

Many small masses of dark diorite crop out in the mountains. Most of them are sandwiched between the layers of gneiss and schist, but a few are in the sedimentary rocks. The largest and best exposures are on Cimarron Creek, just upstream from the Palisades. If the light-colored dacite is described as "salt-and-pepper," the dark-toned diorite is "pepper-and-salt." The "pepper" is dark-green hornblende and a little biotite; the "salt," plagioclase feldspar and a little quartz. Not all the diorite is evenly coarse grained like that illustrated. Some is so fine grained that the crystals cannot be seen without magnification. In larger masses the cores are coarse grained and the borders are fine grained; in places the rock is porphyritic, containing scattered plagioclase phenocrysts.

The diorite was probably intruded into the surrounding rocks when they were comparatively cold. The borders of the intrusive body, chilled by contact with the cold rocks, solidified quickly and became fine grained. In the more slowly cooled core, larger grains grew.