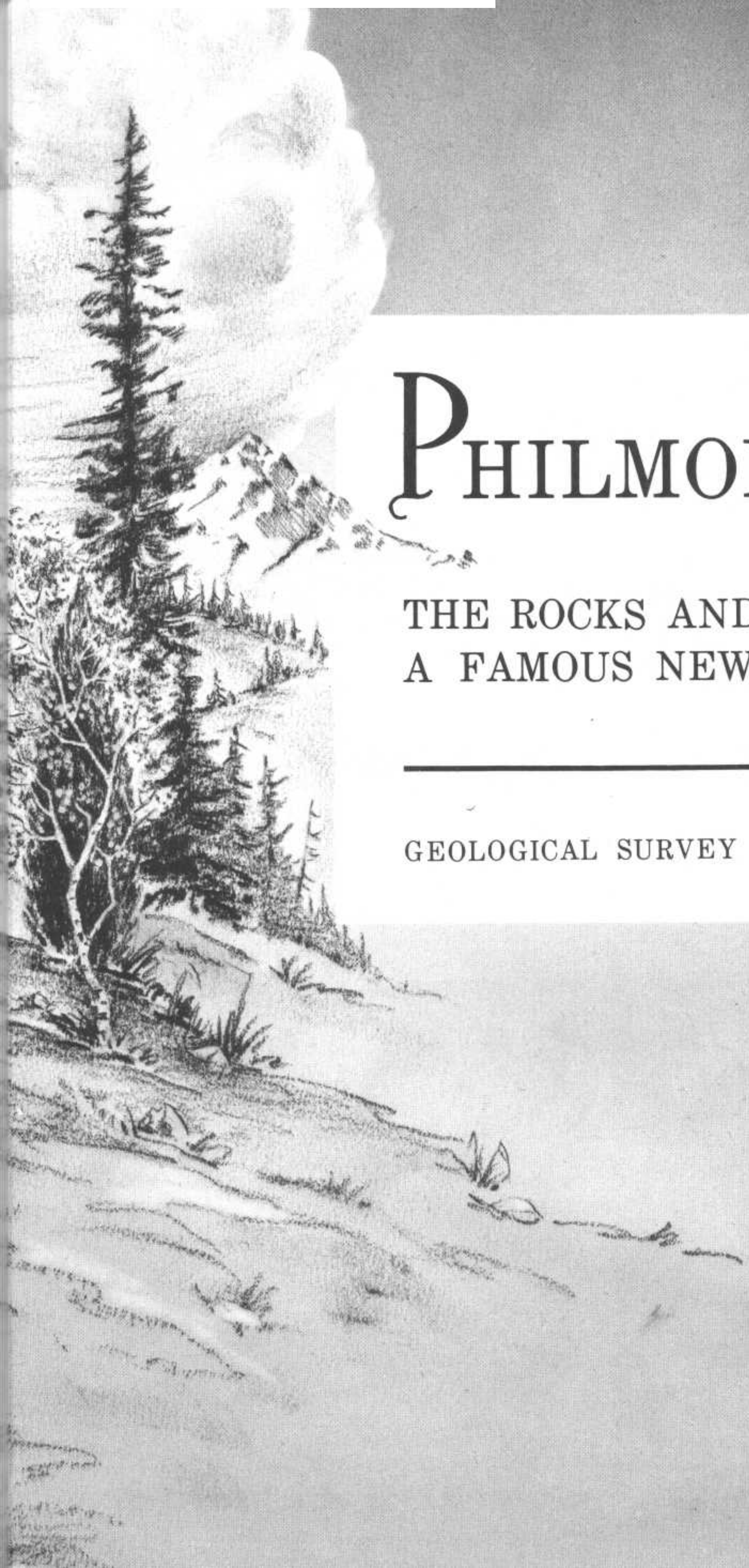

# PHILMONT COUNTRY

## THE ROCKS AND LANDSCAPE OF A FAMOUS NEW MEXICO RANCH

GEOLOGICAL SURVEY PROFESSIONAL PAPER 505

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# Uplift

About half the mapped sedimentary formations of Philmont were formed in the sea and half on land. In succession, the Sangre de Cristo, Dockum, Entrada, and Morrison were laid down on land; the Dakota, near and in the sea; the Graneros, Greenhorn, Carlile, Niobrara, and Pierre, in the sea; the Vermejo, partly on land and partly in the sea; and the Poison Canyon and Raton, on land. All the still younger unnamed formations were also deposited on land. Why did the sea come in and go out? And how did Philmont, which spent most of Mesozoic time near or below sea level, come to be much more than a mile above the sea today?

Has the level of the sea repeatedly risen and fallen hundreds, even thousands, of feet, or are earth movements responsible? Based only on observations at Philmont, we cannot hope even to begin answering this question or a long series of others that logically follow from it. To get the flavor of the problem, we need only remember that if sea level has changed on a large scale, it could not have been merely a local affair but had to be worldwide, for the oceans are all connected. Just to start working on the question would require nothing less than a sampling of the geology of the world, complete with accurate dating throughout, to decide whether submergences and emergences at Philmont coincided with worldwide shifts in sea level or whether they alternated due to more localized earth movements through geologic time. But not nearly enough absolute dates are known, as our earlier discussion of radioactivity dating pointed out, to make this possible now.

If direct human experience is any guide, the odds favor earth movements. Careful measurements prove that some parts of the earth's surface are now rising while others are sinking with relation to sea level, usually at rates of a few inches to a few feet in thousands of years, and historic records show that this rate of movement has held for at least 3,000 years. On the other hand, there has been no detectable change in the volume of the sea and, therefore, no change in sea level in historic time, but there is really very little information with which to work.

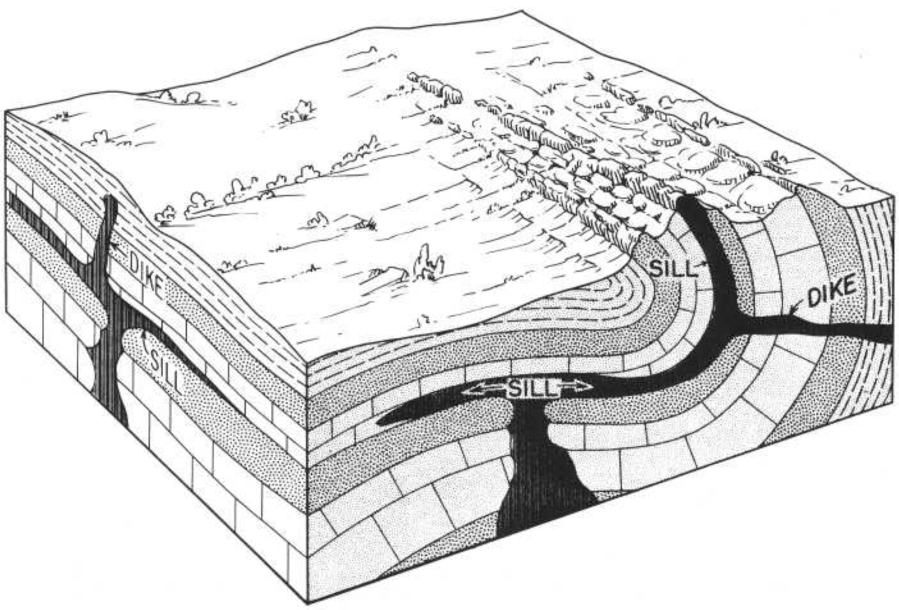
Indirect evidence, however, indicates that the sea itself has risen and fallen, not far back in time. Worldwide rise and fall of sea level amounting to several hundred feet in earlier Quaternary time is strongly suggested by both raised and submerged beaches that have been traced for thousands of miles on several continents and around oceanic islands. These major changes in the total volume of sea water reflect the alternate growth and melting away of several ice sheets of continental size that left their deposits and scars over much of North America, Europe, and Asia. When a large fraction of the earth's water was locked on land as ice, sea level fell; when the glaciers melted, sea level rose.

Worldwide sea level has no doubt been changed in this way, and more than once, but it is not a very useful general explanation of shifting shorelines in the geologic past: in every geologic period there have been major shoreline shifts somewhere, but for only two other times before the Quaternary—in the Permian and in the late Precambrian—is there any evidence of continental glaciation.

If earth movements were responsible for alternating land and sea at Philmont, they were not folding or faulting of the sort we have recognized, except perhaps for final emergence at the end of Vermejo time. Had the sea been let in by downfolding or downfaulting or been forced out by rising folds or fault blocks, such events would be signaled by marked angles between the tilted bedding in the deformed rocks and flat bedding in later rocks. This angle would remain even if the later rocks themselves were deformed. The small angle between the Vermejo Formation and the Raton and Poison Canyon Formations indeed suggests that actual uptilting on the west forced the seashore to retreat eastward at the end of Cretaceous time, but there are no similar signs of deformation to fit the other land-sea oscillations. Indeed, the largest structural events in the last 500 million years seem to have been the folding and faulting that occurred after Poison Canyon time, when the area had long been out of the sea. And even those disturbances can hardly explain the rise of the entire region to its present altitudes. Arching and upfaulting might have brought the Cimarron Range to its present heights, but the plains to the east are far more than a mile above the sea without benefit of recognizable upfolding or upfaulting.

Vertical uplift accompanied by little tilting and on a grand scale seems to be the only answer to the tremendous gain in altitude since Poison Canyon time. It may also explain some of the sea-land shifts of the more distant past. Such wholesale uplifts are part of the geologic record in many parts of the world and at many times in the geologic past.

DACITE PORPHYRY SILL. Light-colored ridge in center is sheet of dacite porphyry intruded parallel to bedding of sedimentary rocks. Across U.S. Highway 64 from Ute Park. (Fig. 114)




SILLS AND DIKES. Sills follow bedding; dikes cut across bedding. (Fig. 115)

# Injections of molten rock

Another kind of dynamic underground process was at work in the rise of every body of igneous rock into the Philmont cake. Knowing almost nothing about the igneous bodies in the Precambrian rocks, we will look only at those in the sedimentary rocks. These igneous rocks made their way upward by either spreading the bedded rocks apart or shoving them bodily away. They certainly did not melt their way up; in fact, they scarcely heated the invaded country, for sedimentary rocks of all colors and kinds are little changed near all but the largest igneous bodies, except for discoloring or hardening within the first inches or feet from the contact. Thus, the intrusion or injection of molten rock has mostly been mechanical: in some way, solid rocks have been moved aside to make room for hot sticky liquids.

Nearly all the many igneous bodies at Philmont are sheetlike, and the sheets are nearly all parallel to the bedding of the sedimentary rocks (figs. 32, 114). Such intrusions along bedding are called sills, another ancient British mining term. Where strata dip steeply, as along the mountain front, sills dip steeply also; where the enclosing beds lie almost flat, as in the northern benchlands, so do the sills, as figure 115 illustrates. Most of the sills are dacite porphyry; a few are andesite, and still fewer are diorite.

The sills are nearly all in shale. Some merely wedged their way in by spreading the shale apart. Others, remarkably, seem simply to have taken the place of the shale. For example, the Dakota Sandstone consists of two sandstone ledges separated by about 100 feet of shale; but in southern Philmont the shale is displaced by dacite porphyry, and for many miles along the mountain front the entire space that should be oc cupied by shale is filled by dacite porphyry, jammed against sandstone on either side.

Where did the shale go? The dacite was not hot enough to metamorphose the sandstone, and it has scarcely a fragment of shaly rock floating in it. The dacite probably did not melt and digest the shale, nor did the shale, which is lighter in weight than the dacite, sink away mysteriously in the depths. Most probably, the shale was partly pushed by the pasty melt and partly floated upward on it above the present level of exposure. An interesting speculation is that, with the help of steam rising from the cooling dacite melt, the shale might have been forced out at the surface to form mudflows that resembled the Quaternary landslides. If so, these rocks were removed long ago by erosion, as they were formed far back in Tertiary time, and no remnant of the land surface at that time is now preserved.

Although most of the intrusive bodies are sills, it is obvious that any melt rising from deep below the sedimentary layer cake must cut across lower layers to get into rocks high in the pile. (See fig. 115; pls. 5, 6.) A few of such crosscutting sheetlike bodies, called dikes, can be seen at Philmont. The largest are in the northwest corner, but these are hard to reach. Interestingly, most of the dikes are andesite and lamprophyre; only a few are of dacite porphyry. This is surely no mere accident but reflects some difference in the age or origin of the various intrusive rocks—what, we do not yet know.

The most accessible dike is the lamprophyre dike on the south side of Horse Ridge. (See figs. 31, 110.) It stands vertically, cutting boldly across shale beds that dip about 20° N. Here we see how dikes may turn and become sills, for that is exactly what the dike does on the east (right) side of the gulch shown in figure 31*A*. Figure 116 is a diagram of this dike-sill. Another easily reached though very small dike, of dacite porphyry, is in the Morrison Formation exposed on Cimarroncito Creek 1.3 miles upstream from the turnoff to Cimarroncito Base Camp. (See fig. 86.)

Tooth of Time Ridge (fig. 117) is part of a sill, but it is a special kind, for its base and top are not roughly parallel; instead, the top is domed up like the cap of a mushroom. Such thickened sills, which seem to have arched their roofs, are called laccoliths (fig. 118). As figure 118 reveals, Tooth of Time Ridge is really a double-deck sandwich made of two laccoliths. The upper one shoved in along the base of the upper part of the Niobrara Formation, and the lower one shoved in at the top of the Carlile Shale, leaving the Fort Hays Limestone Member between. The domelike shape of the whole structure is well shown by the form of the outcrop of the Fort Hays Member, which makes an outward dipping loop about 2½ miles long from east to west and 1½ miles wide from north to south.

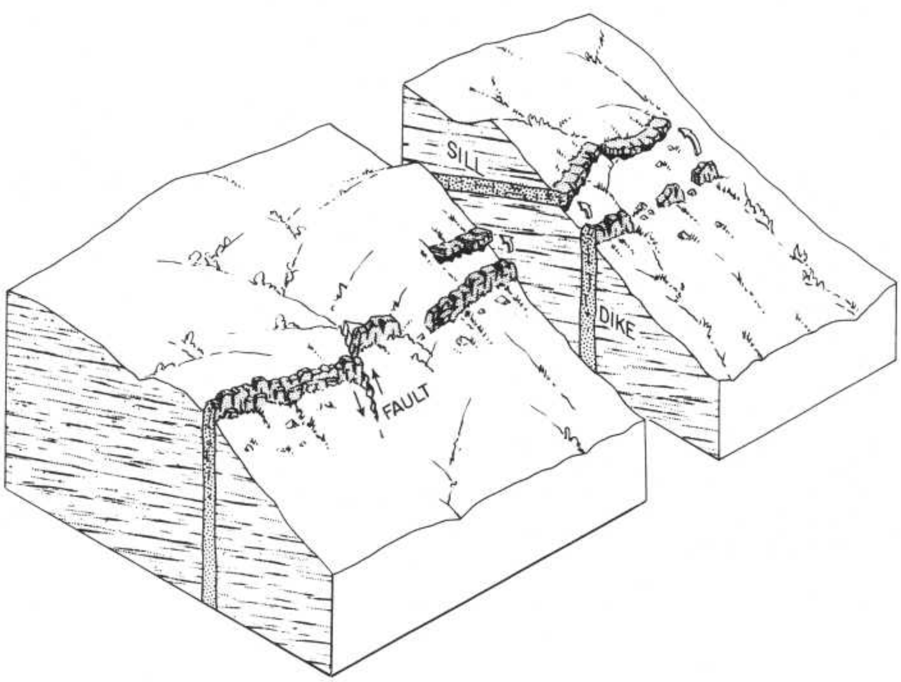
Some laccoliths may have complete mushroom shapes, including stemlike feeders at the base; but many have feeders at the sides, through which the molten rock was injected like toothpaste from a tube. We suspect but cannot prove that this is true of the Tooth of Time laccoliths.

About 30 square miles of high country between Baldy mining camp and Cimarroncito Peak is underlain by a swarm of overlapping laccoliths, to judge by the complicated outcrop pattern of alternating stripes of sedimentary rocks and of dacite porphyry. The peaks seem to be on the crests, or thickest parts, of the largest laccoliths. Such many-storied laccoliths are often called Christmas-tree laccoliths.

At Philmont we cannot tell how the myriad sills were fed. Laccolith swarms in a few other parts of the world, such as the Henry Mountains of Utah, however, are exposed enough to show that their laccoliths were fed mainly from the side by a few large torpedo-shaped masses, called stocks, that extend downward into the earth's crust. Feeder stocks, in turn, may be merely bumps on really huge masses of granitelike rocks, called batholiths, that lie still lower, but no more than 10 to 20 miles down. Possibly, several feeder stocks underlie the Cimarron Range, and they may pass downward into a batholith. Several batholiths having stocks on their backs that radiate sills and laccoliths are exposed farther north along the Rocky Mountain chain, so there is more than just vivid imagination to this idea.

The squeezing, however quietly and slowly, of many cubic miles of molten rock into a small segment of the earth's layered skin was a tremendous dynamic event. It is natural to wonder if this event may not have been closely related to the dynamic events of folding and faulting. The general time relations encourage us to think so. Except for the slightly metamorphosed granodiorite and diorite porphyry which are probably of Precambrian age, all the intrusive igneous rocks of Philmont are of Tertiary age; they are younger than the Poison Canyon Formation but older than the basalt. The same is true of nearly all the known folds and faults. Involved, however, is a fairly long stretch of time, perhaps as much as 50 million years. To narrow the time interval we must look at places where structures and intrusive bodies meet.

The evidence from places where sills meet folds is of little use. True, the sills follow the curve of folded beds, but they might do so whether older, younger, or the same age as the folds. The




LAMPROPHYRE SHEET at Horse Ridge. Sheet is mostly dike but partly sill. (Fig. 116)



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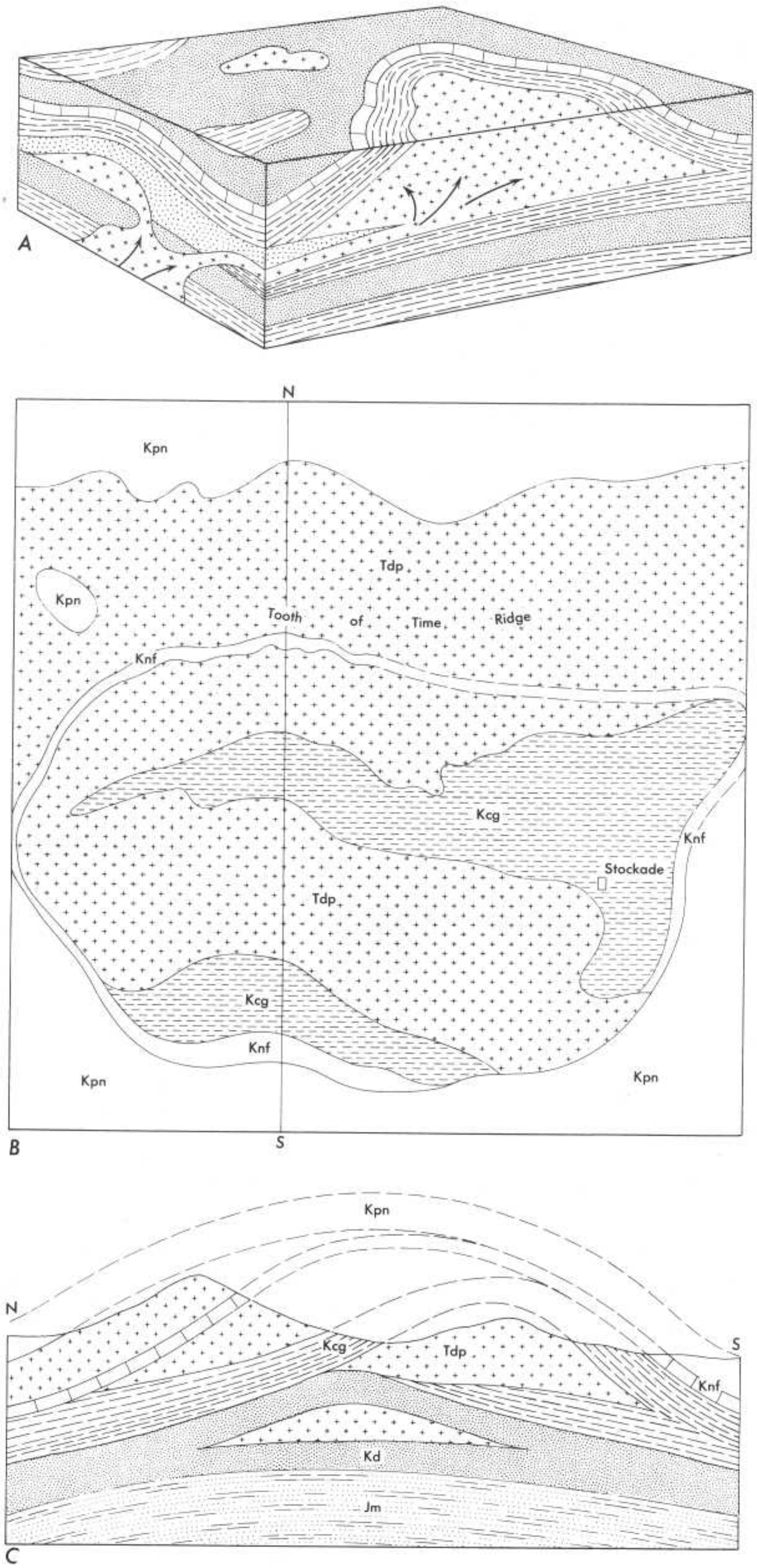
THE TOOTH OF TIME, viewed north from the Stockade on lower Urraca Creek. The Tooth is a spectacularly weathered outcrop of the dacite porphyry double laccolith of which Tooth of Time Ridge is a part. (Fig. 117) straight dikes in folded rocks, as in the northwest corner of Philmont, certainly are younger than the folds; if the dikes are the same age as the sills, then the sills too are younger than the folds.

The relations between faults and intrusives are clearer but even more complex. The Fowler Pass fault is older than the dacite intrusions that obliterate much of it, but the steep Beard fault that goes from Dan Beard Trail Camp to South Ponil Creek cuts and is younger than the great dacite sill of the northern benchlands; and the Sawmill Canyon fault that curves from Maverick Creek, west of Ute Park, nearly to Cimarroncito Base Camp cuts and is younger than several dacite sills. Faulting and the rise of magma into the Philmont cake, therefore, overlapped not only in space but also in time. As the faulting is younger than the folding—but not very much younger—we conclude that Tertiary deformation and intrusion at Philmont were indeed intimately linked.

Just how they were linked is a mystery. It seems clear that the laccoliths pushed up their roofs, but there is certainly not a laccolith to account for every anticline. And how can we account for synclines and for the Cimarron Range itself? There seems to be no superlaccolith beneath the largest anticline of all. Perhaps magma in general does not force its way into the crust but rises quietly where the crust is bulging and rock pressure is therefore low. We do not know enough to justify further speculation.




LACCOLITHS: thick sills that have arched their roofs. A, Sketch of ideal laccolith. B, Simplified geologic map of Tooth of Time Ridge: part of a double laccolith. C, North-south slice across Tooth of Time Ridge. Tdp, dacite porphyry; Kpn, Pierre and Niobrara Formations; Kog, Carlile and Graneros Shales; Kd, Dakota Sandstone; Jm, Morrison Formation. (Fig. 118)

## Volcanic eruptions

The lava flows and bomb beds give the most vivid and direct evidence of subterranean processes that have been at work at Philmont. The molten rock which made them came to the surface through some sort of openings. We do not know where the openings were that fed the thick pile of flows on Ocaté Mesa or what their form may have been—whether they were pipelike and surrounded by a conical pile of erupted material, as is the familiar volcano, or whether they were long fissures and never had a cone shape. But the basaltic rocks that cap Crater Peak, Rayado Peak, Fowler Mesa, and Urraca Mesa were probably erupted from a short-lived volcano that stood a little south of the present Crater Peak. Its surface cone, if it ever had much of one, has been worn away, but the remnants of a small steep-walled flat-floored crater can be seen on the southwest flank of Crater Peak (fig. 119); its feeder has not been found. Most likely the crater was fed through a pipe that has been eroded away or is not yet exposed; but possibly the feeder really is at the surface, partly concealed by slide rock and trees, waiting to be discovered.

The crater filling is just behind the buffalo-head shape of Crater Peak, as seen from the plains north of Rayado Creek (fig. 120).

When the volcano was active, Rayado Creek did not exist, or at least was not very deep. If it had been, the basalt, a tough resistant rock in this climate, would be found far down the valley walls. Surely, then, the volcano ceased to be active long ago. Volcanoes are most likely to break through at the surface along fault zones, especially at the intersection of faults having different trends, so it is no surprise to find a volcano near the intersection of the Fowler Pass fault and the concealed fault that probably controls the course of Rayado Creek. Remember that the Fowler Pass fault dips west, right under the volcano, but is older than the volcano, as lava erupted from the volcano crosses the fault without offset.

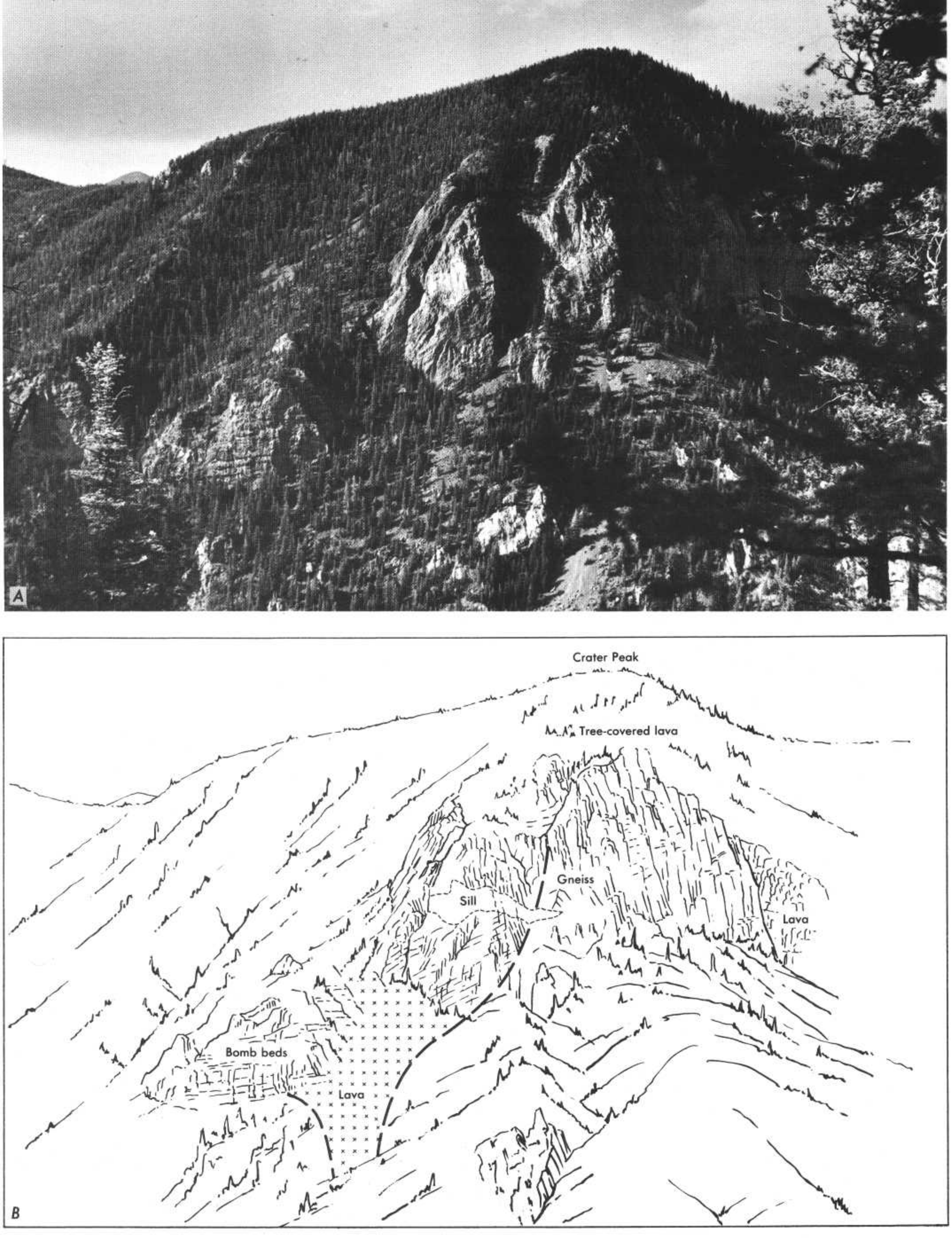
## Ground water in folded rocks: Artesian water?

Earlier, in considering ground water, we feared that the present sources of water—streams, lakes, reservoirs and shallow wells—might not be able to support much expansion of ranching and camping even if energetically developed; and we wondered if large sources of water, perhaps under pressure, might not exist deep beneath the thirsty plains. But without knowing about the distribution, sequence, and structure of possible water-bearing rocks, we could not pursue the matter. Now we can.

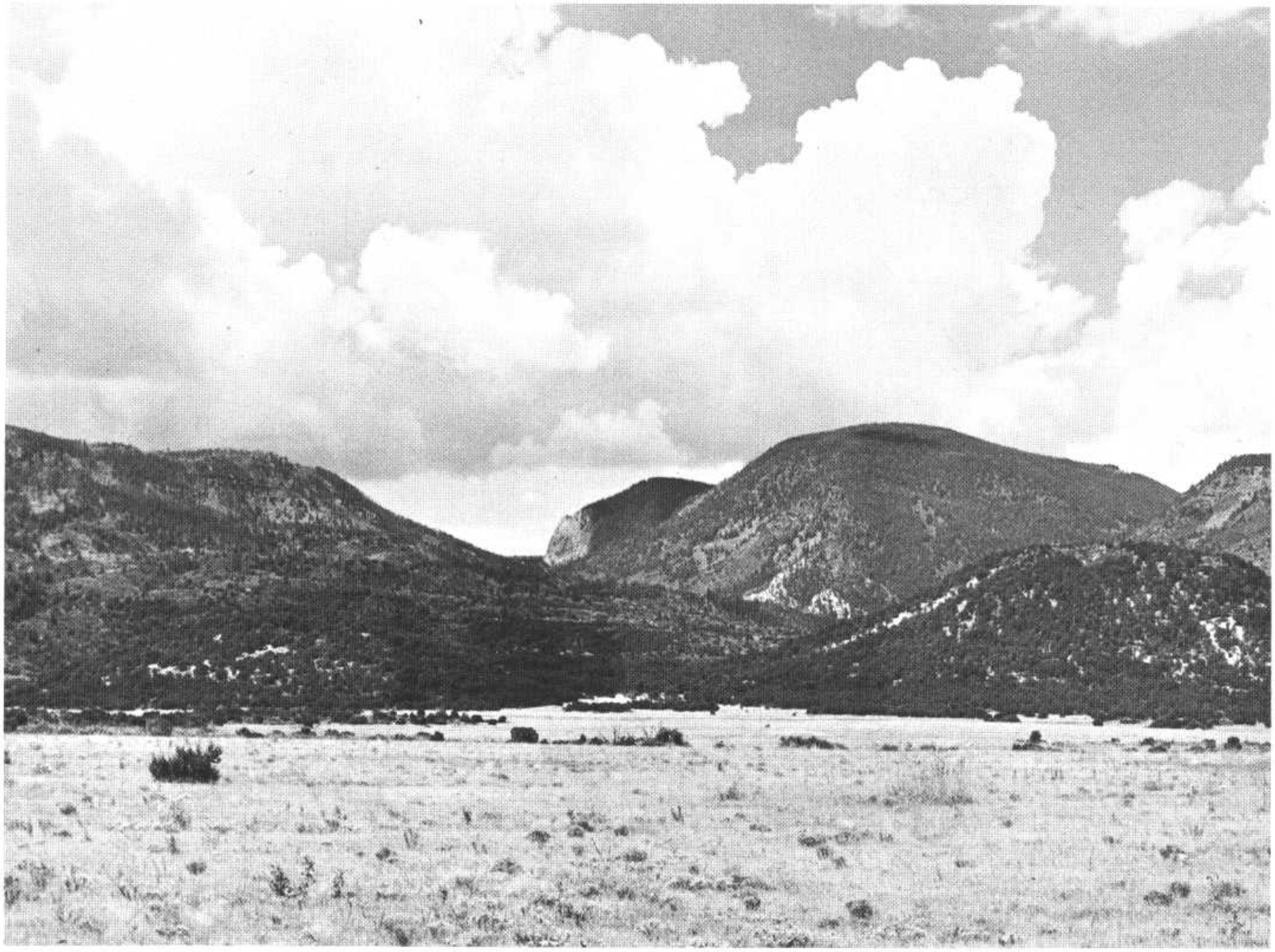
Only rocks made of sand and gravel and having large connected pores are likely to be good carriers of water, or aquifers. At Philmont such rocks are abundant in the Sangre de Cristo Formation, Dockum Group, and Entrada, Dakota, Trinidad, Raton, and Poison Canyon Formations. But most of these were laid down rapidly by rivers on land: fine particles of clay and mica were not washed out, and the pores tend to be clogged; further, the individual sandstone layers, though in places very thick, probably do not continue very far but are lenses surrounded by shale. Many poor or dry wells already drilled in the Poison Canyon and Raton Formations show that these units are not promising aquifers; there is no reason to think the stream-laid Sangre de Cristo or Dockum rocks would be any better. This leaves the cleaner, more uniform and rounder dune or beach sandstones of the Entrada, Dakota, and Trinidad Formations.

To supply much water over a long time, our imagined aquifers must not only hold much water but must crop out where there is plenty of rain and snow for recharge—that is, in the mountains. This rules out the Trinidad which was eroded from the mountain area before the Raton Formation was deposited and crops out only in the northern benchlands. But the two thick sandstone layers of the Dakota, 100 feet apart, and the Entrada Sandstone, 400 feet lower, are still in the running. Indeed, the Dakota seems to be a winner, as it is a known major aquifer far out on the plains, where thousands of producing wells have been drilled in it.

Where they crop out along the relatively rainy mountain front, the Dakota and Entrada dip rather steeply eastward. Almost certainly, they flatten out beneath the benchlands to the north and the plains to the east (see the structure model, pl. 6, and the geologic sections, pl. 5), but nevertheless they are far beneath places where much new water is likely to be needed, as at the base camps of the Scout Ranch. The top of the Dakota Sandstone is probably about 4,000 feet beneath Ponil Base Camp, less than 2,000 feet beneath the Camping Headquarters, about 1,000 feet beneath Carson Maxwell Base Camp, and perhaps as little as 800 feet below New Abreu Base Camp. Add about 550 feet to reach the Entrada.



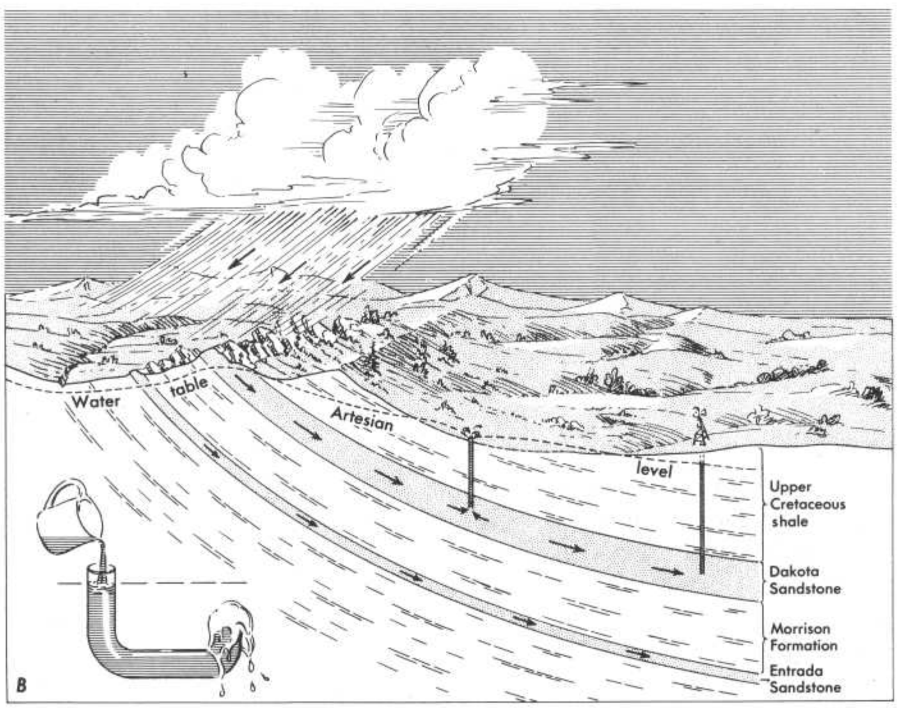

CRATER PEAK, an eroded volcano. A, View from the south. B, Geologic sketch. (Fig. 119)



CRATER PEAK, viewed from the plains north of Rayado Creek, has the shape of a buffalo head. The face is light-colored Precambrian gneiss; the hairy cranium is basalt. Just beyond the face, hidden from view, is the eroded crater that gives the peak its name. (Fig. 120)

Some day the trial will be made, possibly as a side issue in drilling for oil. When it is made, there is a good chance that abundant water will be found in both the Dakota and the Entrada and that the wells will be artesian—that is, the water will rise far above the aquifer, though probably not to the surface, without pumping. A good reason is that the flowing artesian well at Ute Park mentioned earlier is in the Dakota Sandstone (fig. 121). The unimpressive-looking trickle of water in the photograph is really the top of a water column 167 feet high, pushed up by its own pressure from its source in the Dakota, which crops out only 500 feet to the West.

Why does the Dakota yield artesian water? Figure 121*B* may help explain. Water entering the Dakota Sandstone and flowing down the dip to fountain out at Ute Park or to rise high in wells under the plains may be compared to water poured into a J-shaped tube. As everyone knows, a little water poured into such a tube will rise to the same level on both sides; if the water level in the long arm is kept higher than the top of the short arm, a fountain results. If the tube is filled with sand, the situation is not changed very much except that the water will not rise as high or as rapidly in the outlet side because of the frictional resistance of the sand grains. In our natural artesian system, the long intake arm of the tube is the outcropping Dakota Sandstone, the walls of the tube are the impermeable shales that lie above and below the Dakota, and the short outlet arm is a well.


ARTESIAN WATER at Philmont. A, Flowing artesian well, 167 feet deep, at Ute Park. B, Possible artesian flow from the Dakota and Entrada Sandstones. (Fig. 121)