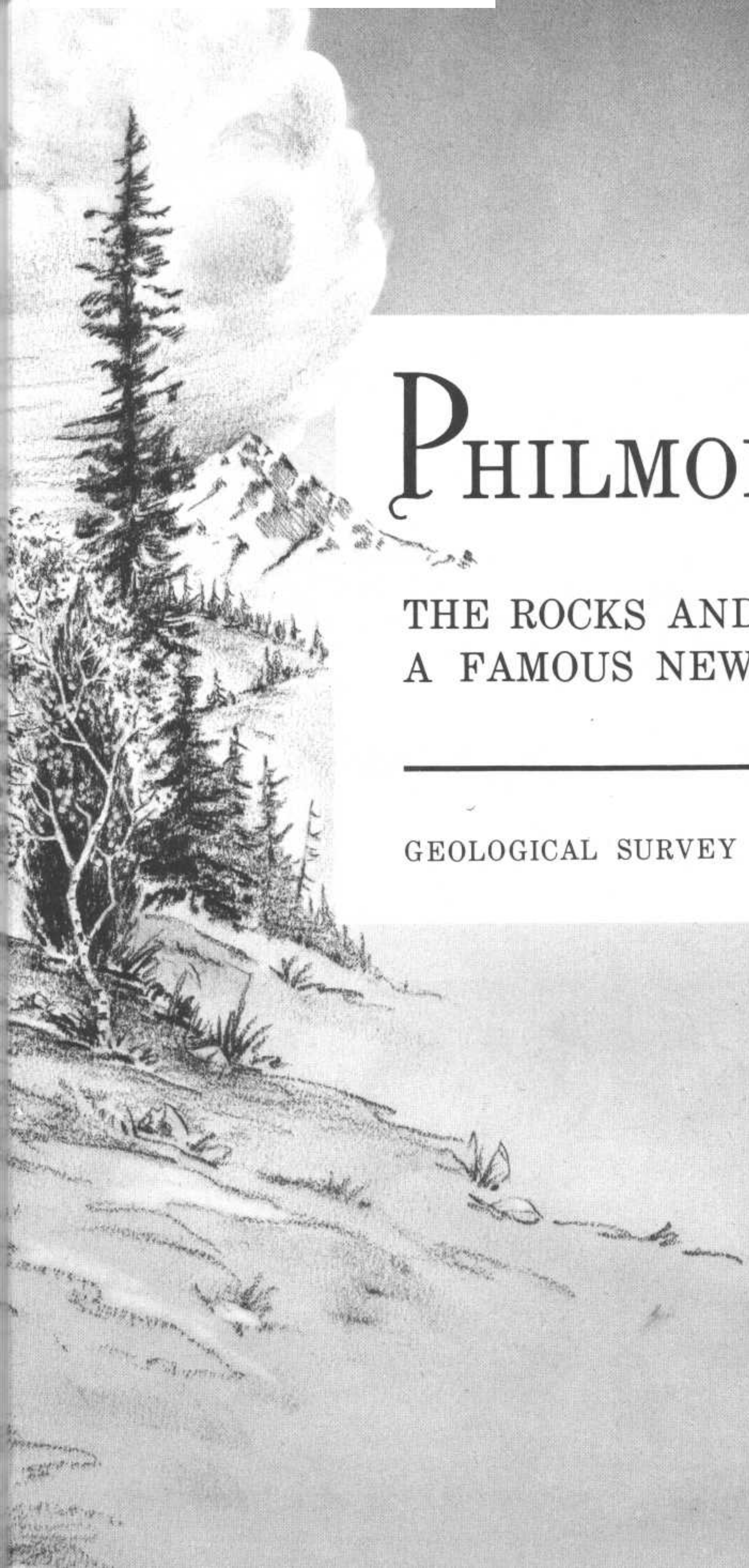

PHILMONT COUNTRY

THE ROCKS AND LANDSCAPE OF A FAMOUS NEW MEXICO RANCH

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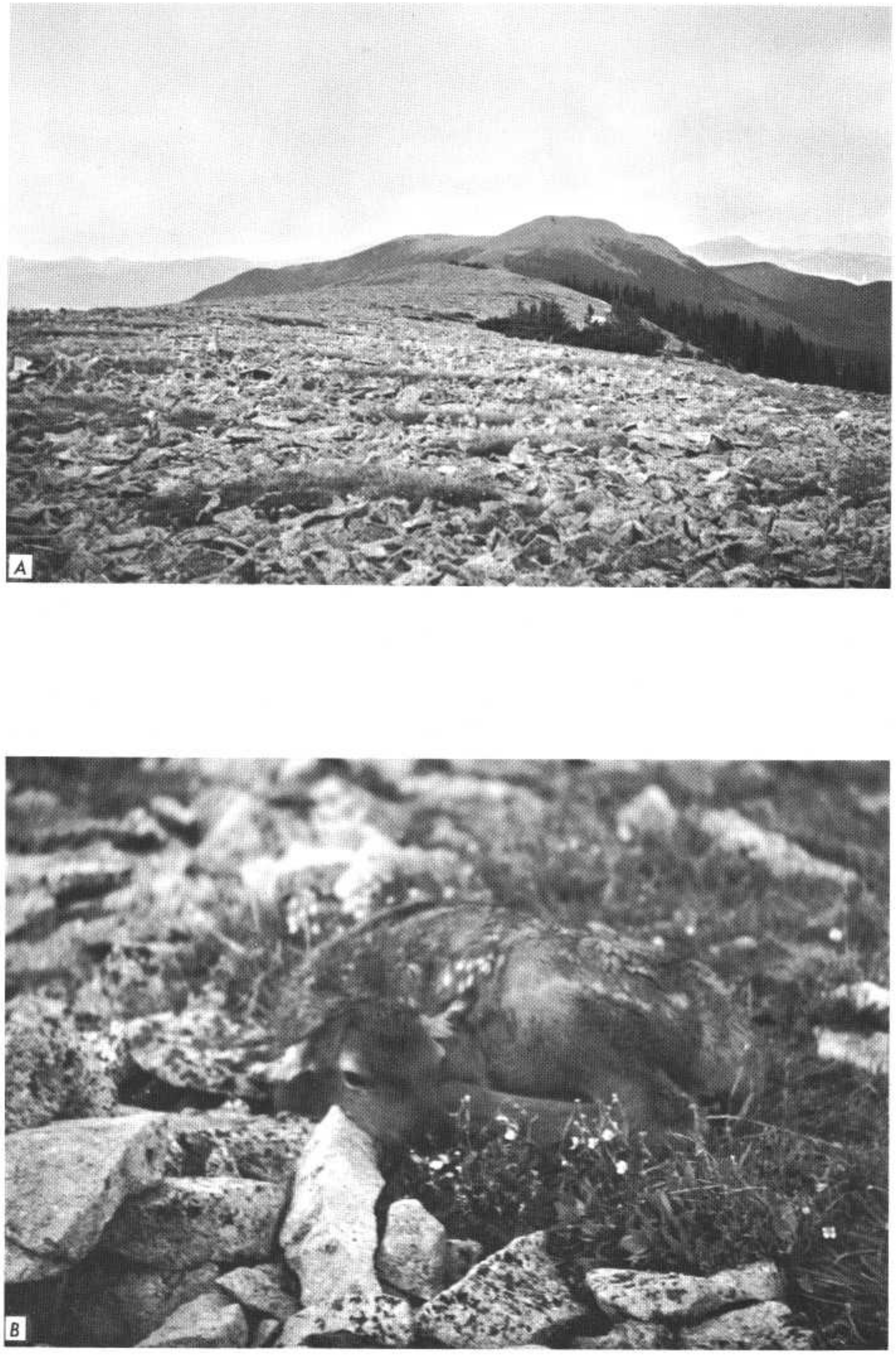
Rubble

We will speak briefly about one kind of rock that can be seen only after some effort. Far from roads or trails, near timberline on Touch-Me-Not and Baldy Mountains, the bare rock surfaces are mantled with sharp-edged rubble. By watching long enough, we learn that this rubble is the result of frost action. First, rain and melt water work down into cracks in the rock; when this water freezes, it expands, widening the cracks and eventually causing pieces of the rock to break off. On very low slopes, the rubble does not move far but forms large fields of sharp-edged blocks (fig. 75*A*) or forms stony networks around clumps of grass or stunted trees (fig. 75*B*). On steeper slopes, masses of blocks lubricated by rain or melt water sometimes flow slowly downhill like a glacier and come to rest in long, low ribbonlike piles (fig. 76). The furrowed treeless slope in the center of the view in figure 76, on the east flank of Touch-Me-Not Mountain, is made by a large rubble stream. The furrows show that the stream moved in waves.



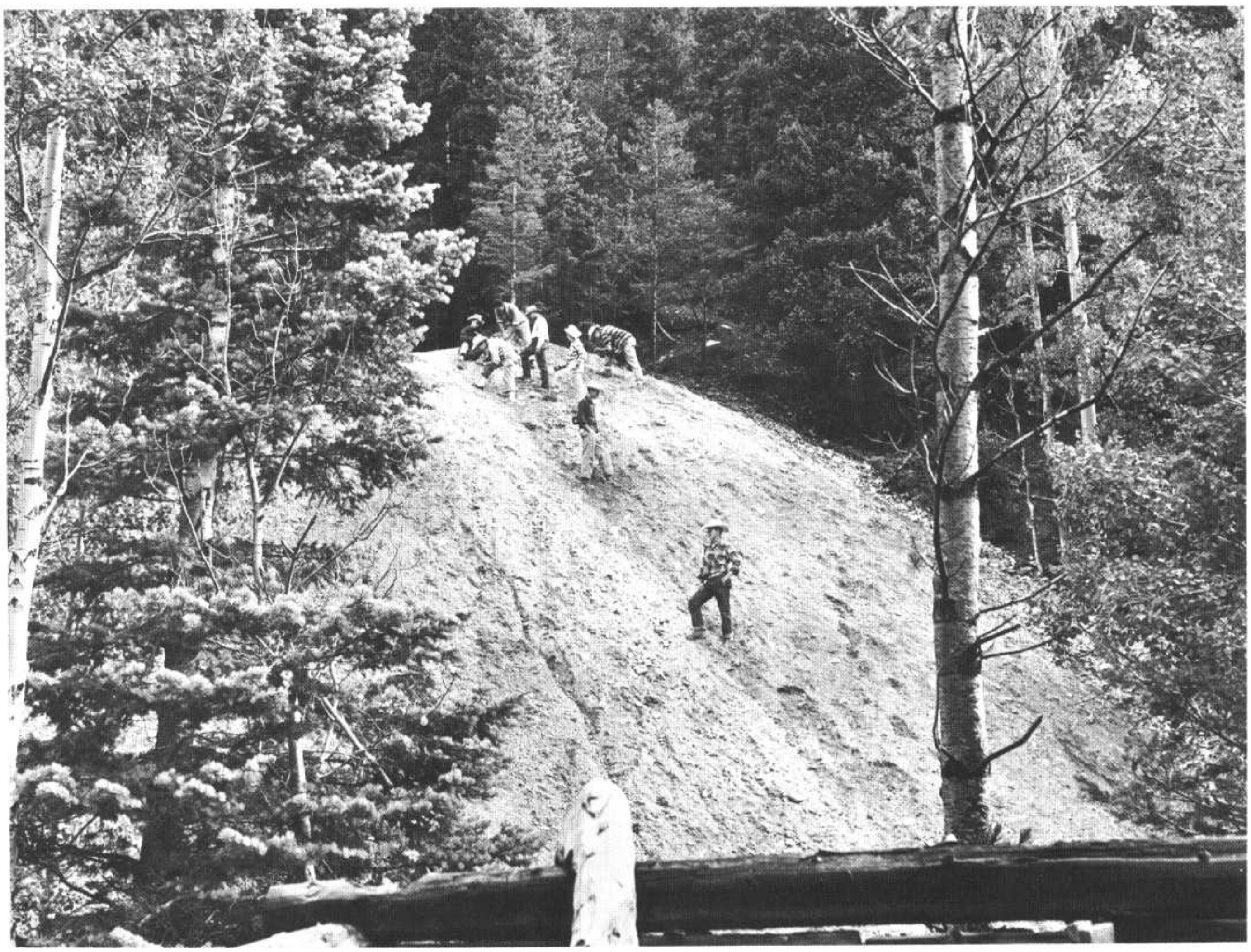
BLOCK FIELD, formed on gently sloping land. A, Continuous block field. B, Close-up view of stone net; elk calf in center. (Fig. 75)

Ore deposits?

Knowing that gold has been mined high on Baldy Mountain in and near dacite porphyry sheets, we are not surprised to find mine workings near outcrops of dacite porphyry on the northeast slopes of Comanche Peak. Near the heads of both Middle Fork and North Fork Cimarroncito Creek are several short tunnels that have bare piles of broken rock at their mouths (fig. 77). These workings, like those near Baldy Mountain, are abandoned. Indeed, no ore worth mining seems ever to have been found in the few years of prospecting, early in the century, when these tunnels were dug.

BLOCK STREAM, formed on steeply sloping land. (Fig. 76)

EXPLORER SCOUTS ON THUNDER MINE DUMP, Middle Fork Cimarroncito Creek. (Fig. 77)



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In the dirt-encrusted tunnel walls and in fragments of altered limestone, sandstone, shale, and dacite on the dumps are only a few signs of ore minerals: scattered crystals of yellow pyrite, red-gold chalcopyrite, and silvery specularite, and films of green malachite. No gold is visible (it is rarely visible even in rich deposits); but some fairly high gold contents were reported in old assays, and gold colors can be panned in places downstream on Cimarroncito Creek. Rusted mining tools and machinery left behind by the disappointed miners are perhaps more interesting than the specks of ore minerals.

It is not hard to decide where the malachite films came from: ground water containing carbon dioxide has dissolved chalcopyrite (copper-iron sulfide) and precipitated malachite (copper carbonate + water). But how the chalcopyrite itself and the other ore minerals got into the rocks we cannot tell from the tantalizing bits of evidence, except that they seem in some way related to the dacite porphyry sheets. Most gold-copper deposits the world over are in fractures in and near granitelike igneous rocks, suggesting that the metallic minerals were deposited by hot fluids that rose from below soon after the igneous rocks solidified.

Thoughts about rocks

Thinking about the rocks of Philmont, we become aware that, in spite of their great diversity—in appearance, color, hardness, grain size, resistance to erosion, and so on—they formed in only three ways. They are either sedimentary rocks that settled out of some transporting medium, generally water; or igneous rocks that cooled from a melt; or metamorphic rocks that were changed in the solid state from preexisting rocks by great heat and pressure. In this the Philmont region, a mere speck on the planet, provides a fairly good sample of the earth's skin, which is made wholly of rocks that are either sedimentary, igneous, or metamorphic.

Of the sedimentary rocks at Philmont, most were transported and deposited on land by streams, but some formed in the sea. (Most sedimentary rocks of the world, however, were laid down in the sea.) Wind may have made some of the crossbedded sandstones of Philmont. Gravity, of course, governed the moving and dropping of all the sediments and was, with little help, responsible for the hummocky landslides and the mountain rubble deposits. But we found no rocks of the sort that are made by glaciers, and we conclude that there have been no long-lived glaciers in the Cimarron Range, high as it is or may have been.

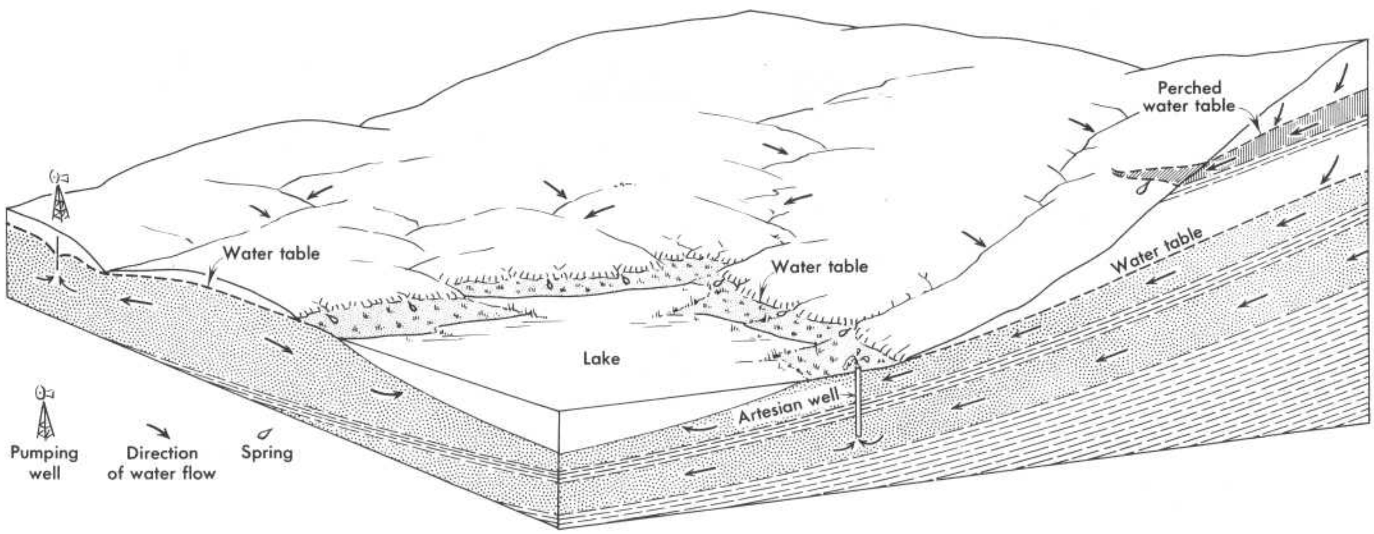
We have met many varieties of igneous rocks, from wholly coarse-grained ones that cooled slowly at depth, through porphyries that had distinct stages of cooling underground, to glassy frothy lava chilled by the cold air at the surface. Several kinds of common igneous rocks that we might have hoped to find are missing, however: there is no granite; there are no fine-grained glassy lavas of the same composition as the dacite, granodiorite, diorite, lamprophyre, or andesite, all of which cooled below the surface; and there are no coarse-grained rocks chemically like the basalt lava. Too, there are only the small area of bomb beds at Crater Peak and the scattered thin layers of orange shale to remind us of the igneous rocks, abundant in many parts of the world, that settle out of the air after explosive volcanic eruptions.

Our assortment of metamorphic rocks is skimpy, and our knowledge of those which do occur is slight. For example, Philmont has no marble, the familiar rock that is metamorphosed limestone. Also missing are the many kinds of metamorphic rocks in which minerals that are rare in sedimentary and igneous rocks have grown in profusion, like the garnet in garnet schist.

Too, we have seen almost nothing of those odd and rare but potentially valuable rocks called ore deposits, and we have given little thought to how they form.

Varied as they are in origin and appearance, the main rocks of Philmont—and of the earth—are made mostly of only a dozen or so minerals. We have named about 30 minerals and probably could find small amounts of several hundred if we looked hard enough, but only a few are abundant enough to be thought of as rock formers. The most common minerals at Philmont are quartz, plagioclase, hornblende, and biotite, and they are very common in all three classes of rocks. Other rock-forming minerals are orthoclase, pyroxene, olivine, muscovite, chlorite, calcite, clay, and coal. Of these, muscovite is widespread in all three rock classes. Pyroxene and olivine are abundant only in the dark-colored igneous rocks; orthoclase, in the light-colored igneous rocks; and chlorite, calcite, clay, and coal, in the sedimentary rocks.

The differences among the three classes become even smaller when we realize that some of the minerals that are more or less limited to one class are really very much like minerals common in the other



WATER IN THE GROUND: the lake beneath us. (Fig. 78)

classes. For example, chlorite is chemically much like biotite and hornblende but contains more water than either, and clay is chemically like feldspar but contains water. We realize, too, that although the metamorphic rocks have a few unusual minerals, like garnet, they are mainly made up of the minerals common to the igneous and sedimentary rocks.

We have actually seen sand and gravel forming at the surface from the weathering and erosion of sedimentary, igneous, and metamorphic rocks. This process also goes the other way, as sediments are deeply buried, compressed by their own weight, and heated. First, they become dried out and cemented; then, as temperature and pressure increase, they are transformed to metamorphic rocks; and then, in turn, if they get hot enough to melt partly or wholly, they may begin to flow and, later, to cool as igneous rocks. The principal chemical change in weathering is a gain of water, both in the rock pores and in the minerals themselves. The principal chemical change in metamorphism is the loss of water. So we come to think of the rocks of the continents as endlessly but slowly passing through a cycle of crystallization⟶weathering⟶erosion ⟶sedimentation⟶recrystallization; they gain water near the surface and lose it at depth. Perhaps some of the rocks of Philmont have been through more than one complete cycle, whereas others—such as the basalt lava—may be on the earth's surface for the first time.

Water in the ground: The lake beneath us

Most of Philmont's surface materials have plenty of open spaces. Soil, gravel, sand, sandstone, and conglomerate all have many obvious air spaces, or pores, between grains—usually 10 to 30 percent of the total rock volume. Even the igneous and metamorphic rocks, whose crystals are tightly interlocked, have many open cracks near the surface. When rain falls or snow melts, part of the water trickles down through these openings. Not many thousands of feet below the earth's surface, however, all the openings in rocks, both pores and cracks, are closed by rock pressure, cementation, or crystallization, as is shown by deep borings and by laboratory experiments. Eventually, the water reaches a level below which it cannot percolate, and then it fills the rocks to a level above which it overflows at the surface in springs or seeps (fig. 78).

The rocks at Philmont are already filled to the level of overflow, for there are hundreds of small springs on the sides and in the floors of valleys from the mountains to the plains. The rocks of Philmont are a vast, though leaky, subterranean reservoir. The top of this ground-water reservoir is known as the water table.

Philmont's springs are places where the water table meets the surface. As there are many springs in the high mountains at Philmont as well as on the plains, the water table is not very deep and is not flat—the word "table" is not very apt—but rather is shaped much like the land surface would be if the canyons were filled. The altitudes of springs show that the water table is highest in southwesternmost Philmont, where it is around 10,100 feet above sea level, and is lowest, about 6,400 feet, near Cimarron town. Its average northeastward slope is about 200 feet per mile; probably it does not slope evenly, but is flatter than this within the mountains and on the plains, and steeper across the mountain front. Water flows downhill whether above ground or below, so that ground water is flowing from the mountains to the plains.

How fast does this water travel? By comparison with streams, the ground water is moving down fairly steep slopes—somewhere between that of Cimarron Creek (70 feet per mile) and that of Cimarroncito Creek (250 feet per mile). Such slopes, though, do not mean that the water rushes along the water table like a mountain torrent; we know it does not, for the springs flow quietly. Rather, it means that ground water, to move at all, must have considerable fall to overcome the frictional resistance of the rock grains and narrow cracks through which it passes. The real rate of flow along the water table at Philmont is unknown.

Ground-water flow has been measured at a few other places by putting dyes or radioactive tracers at intake points and waiting until they show up in the water at springs or wells. In country having geology and climate similar to those of Philmont, an average drop of water may travel 50 feet a year, or a mile a century. Some of the fresh clear water you might drink from the springs on Wilson Mesa may have fallen on Baldy Mountain, 7 miles away, during the time of the Crusades. Most of it, no doubt, has had a less interesting history, having fallen more recently and much nearer.

The springs in most of Philmont issue only from porous sandstone and conglomerate, generally where they lie on shale, which acts as a water barrier because its pores are so narrow and poorly connected that water can scarcely move through them; or on dacite porphyry, a water barrier because it does not have any pores. Some of Philmont's intermittent springs may come from ground water trapped above the regional water table by local water barriers, such as shale beds. Such water bodies are thought of as "perched," and their tops are called perched water tables (one is shown in figure 78).

In southwestern Philmont most springs issue from the base of basalt sheets, which are water carriers because they are riddled with bubble holes and have cracks formed during cooling. The basalt sheets lie on gneiss and schist that have no pores. From this we realize that although all the rocks below the water table hold as much water as they can, they will not all yield water.

Wells may be thought of as artificial springs. At Philmont there are scores of wells, most of them on the low plains in Cimarron town and near the Scout camps, but some are on the high benches. Nearly all are less than 100 feet deep and draw their water from loose gravel or sand. Many more, drilled just as deep or deeper, have never yielded water or have run dry and been abandoned, showing that not every hole drilled through the water table will become a dependable producing well. Indeed, only wells that penetrate water-soaked rocks made of sand or gravel can be counted on at Philmont. Wells in igneous and metamorphic rocks produce if they happen to penetrate wide crack systems below the water table. Wells in shale, no matter how far below the water table, are dry; water will not pass through the narrow pores in this rock, and fractures cannot stay open because the rock is made mostly of soft clay.

After several especially dry years, some of the springs and wells in both the benchlands and plains have been known to become dry, showing that the water table has dropped. Even when there has been no general drought, some wells have gone dry because they were pumped faster than the ground water could flow to the well, artificially lowering the water table around the well intake. Indeed, some wells have gone dry without being pumped at all because the local water table has been lowered by overpumping at other wells nearby. Once the water table falls below the bottom of a well, the only quick solution is to deepen the well; for, as we have seen, the rate at which ground water flows back, or recharges, is very slow, even when plenty of water is available.

Every perennial stream at Philmont is partly fed by springs; otherwise, it could not flow in dry seasons. A perennial stream might even be defined as a place where the water table is consistently above a stream bed. If it is not, dry and flowing stretches may alternate.

You may have heard about or seen desert basins in which rivers descending from mountains vanish into the ground. This is no tall story or mirage in reverse; the Humboldt River in western Nevada is just one of many examples. The water table, which is above the river bed in the mountains, dips below the surface in the desert. Instead of ground water flowing off the water table into the river, it flows down the buried water table and either reappears miles downstream or remains in the basin until tapped by wells or by down-cutting streams.

The permanent natural lakes of Philmont are in places where the water table intersects the surface of a closed depression. If it did not, the water in the lakes would soon disappear by evaporation and by sinking into the ground. All the lakes and reservoirs on the dry lowland plains are manmade; the water table there is well below the surface. Because they are above the water table, they may disappear in dry years and, therefore, are not dependable water sources.

The combined water resources of streams, reservoirs, and shallow wells are able to fill the needs of the residents but are strained by the thousands of visitors during the hottest, driest months of the year. The permanent natural lakes, unfortunately, are too far from settlements to be of much use; besides, they are small. The number of summer visitors is increasing, and the water supply must be increased too. More reservoirs could be built, and evaporation from all standing water bodies could be greatly reduced by covering them with plastic film. More shallow wells could be drilled near camps. Whether efforts like this would repay the cost is uncertain. Perhaps new sources of water should be sought.

A possible new source is suggested by one small flowing artesian well that has been drilled into quartz sandstone near the mountain front at Ute Park. This particular well is of no use because it is not only feeble but is contaminated by marsh gas, but it raises an interesting question. Water can flow upward only if it is under pressure. Is it possible that large supplies of ground water under pressure exist deep beneath the plains of Philmont? Before considering this possibility, however, we must know more about the arrangement of the rocks beneath the surface, for special conditions are obviously needed to put ground water under pressure.