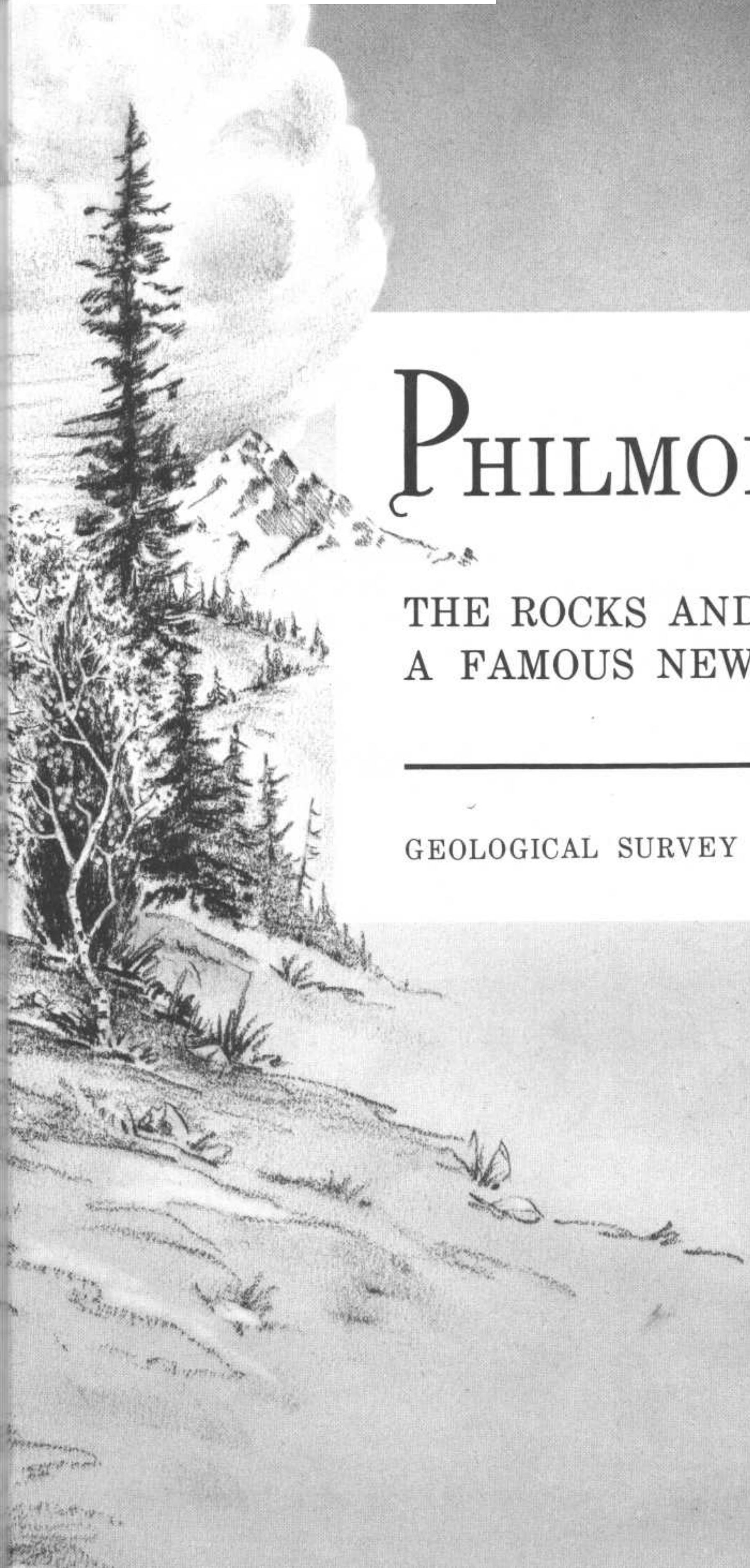

PHILMONT COUNTRY

THE ROCKS AND LANDSCAPE OF A FAMOUS NEW MEXICO RANCH

GEOLOGICAL SURVEY PROFESSIONAL PAPER 505

A CLOSER VIEW: The rocks, fossils, and water beneath the land

Coming closer to the ground, we discover that Philmont has a dazzling variety of rocks—the materials of the earth's hard skin. Every kind of rock that is common on the earth as a whole is present here, as well as some rare types. Naming rocks is not easy, for in the realm of rocks, as in all natural realms, there are few sharp divisions. Rocks grade by small changes in appearance and composition into other rocks. Geologists give them definite names and arrange them in classifications in the hope of finding hidden order in outward chaos. In our search for order, we will divide the rocks of Philmont into about 20 types. The names they are given are convenient handles; not all should be taken very seriously.

The origin of rock names is a fascinating subject in itself, but one we will not go into very far. Some names are descriptive: the name "granite," for example, given to a certain rock made of coarse crystal grains, stems from the Latin word *granum*, meaning grain; and the name "schist," given to a finely layered crystalline rock that splits easily, comes from the Greek word *schistos*, meaning divisible. Other rocks are named for places where they are common—dacite is named for *Dacia*, a Latin name for lands that are now part of Romania. Still other rock names, such as basalt, are so old that their origins are forgotten.

Only about half a dozen of the 20 named rocks are important in volume. The rest are interesting curiosities which happen to be fairly easy to see and reach. Some others, just as interesting, are not mentioned because they are hard to see or to reach.

A rock is simply a natural mineral collection. Nearly all rocks are made of crystals or fragments of several minerals; a very few are made of many crystals or particles of a single mineral. The minerals in rocks are not often easy to recognize, even for mineral collectors, as they are seldom in large well-shaped crystals of the sort usually pictured in books or displayed in museums. Large well-formed crystals are rare—that is why they are collected and exhibited. The minerals in most rocks are in small grains that have poor crystal outlines or none, owing to conditions of growth or to wear. To help identify the rock-forming minerals of Philmont and the rocks they form, all the minerals and rocks mentioned are illustrated by photographs of ordinary specimens.

Fossils are parts of rocks, and they tell a great deal about conditions when they were buried. Therefore, fossils are discussed along with the rocks in which they are found. They too are illustrated, but we are not so generous with information on hunting grounds—these you will have to find for yourself! Soils are rocks, too, and an extremely valuable kind to man; but we will have nothing to say about them because we did not study them.

If we are to make more than a geologic shopping list, we must not only find and name the main rocks but also decide how they formed and when. "When," we will leave until a later chapter. "How," we will consider briefly for each rock. For most rocks, this is not a mere guessing game, though we have space to present only a little of the evidence.

Many common rocks can be caught in the act of forming. For example, every few years white-hot lava pours out on the earth's surface in such places as Hawaii and Mexico, and freezes to black basalt. On any beach we can see sand being rounded and sorted by waves and currents, and we can observe the kinds of animals and plants that live and are buried there. If the basalt that has cooled before our eyes is in nearly every way like a rock long cold, then the old rock may also be basalt that poured out on the surface. A sandstone that is identical, except for the cement that holds the sand together, with beach sand in which we have dug, and has in it the remains of animals like those we have seen on beaches, probably formed on an ancient beach. If the basalt is now covered by other rocks, so that it is no longer obvious that it flowed on the surface, or if the sandstone is far from the sea, we need not decide that the other direct observations are worthless. Rather, we conclude that much has happened to these rocks since they formed. In thus using what is known from direct experience to interpret events distant in space or time, we are using both simple common sense and a basic scientific principle that goes by the name, "uniformitarianism."

The method of learning about the faraway and long ago by comparison with the near and present works well for events that can be watched, but not all geologic events can be observed. Some natural processes—the building of a mountain range or the evolution of an animal species—take so long that direct comparison based on experience is impossible. And many events of geologic importance take place only far below the surface, beyond observation. Certain rocks, for example, have never been seen forming at the earth's surface. Even if they are now forming deep below the surface, we cannot watch what happens, and there must always be some doubt about their origin. But we can learn much even about slow or hidden happenings by studying related natural processes and events that can be observed and by making laboratory experiments under conditions that are thought to exist naturally but that cannot be observed.

The common coarse-grained crystalline rock called granite is an example. Although it has never been seen forming, some of it, at least, surely forms by the cooling of a rock melt deep within the earth's crust. This seems a safe conclusion because lava of the same chemical composition as granite, and containing the same minerals, has often been seen flowing from volcanoes and cooling on the surface to become the rock called rhyolite. The only difference is that the lava is made of tiny crystals, whereas granite is made of much larger ones. As everyone who has made fudge knows, the slower a melt cools, the larger the crystals that grow from it. Therefore, it is reasonable to think that granite may form from the slow cooling of a melt like that of rhyolite. And a rhyolite melt will cool slowly if it is under a thick insulating blanket of rock—that is, deep below the surface.

We can go farther. In the laboratory, practically all the conditions that are likely to exist anywhere on the earth's surface or in its outer crust can be reproduced, though on a very small scale. We can actually find out how granite or a granite melt behaves in the laboratory and gain many clues to the way it behaves in nature. So by using as many direct observations as possible and as many indirect ones as necessary, we can come to conclusions of varying certainty about the ways in which rocks have formed, at Philmont and elsewhere.

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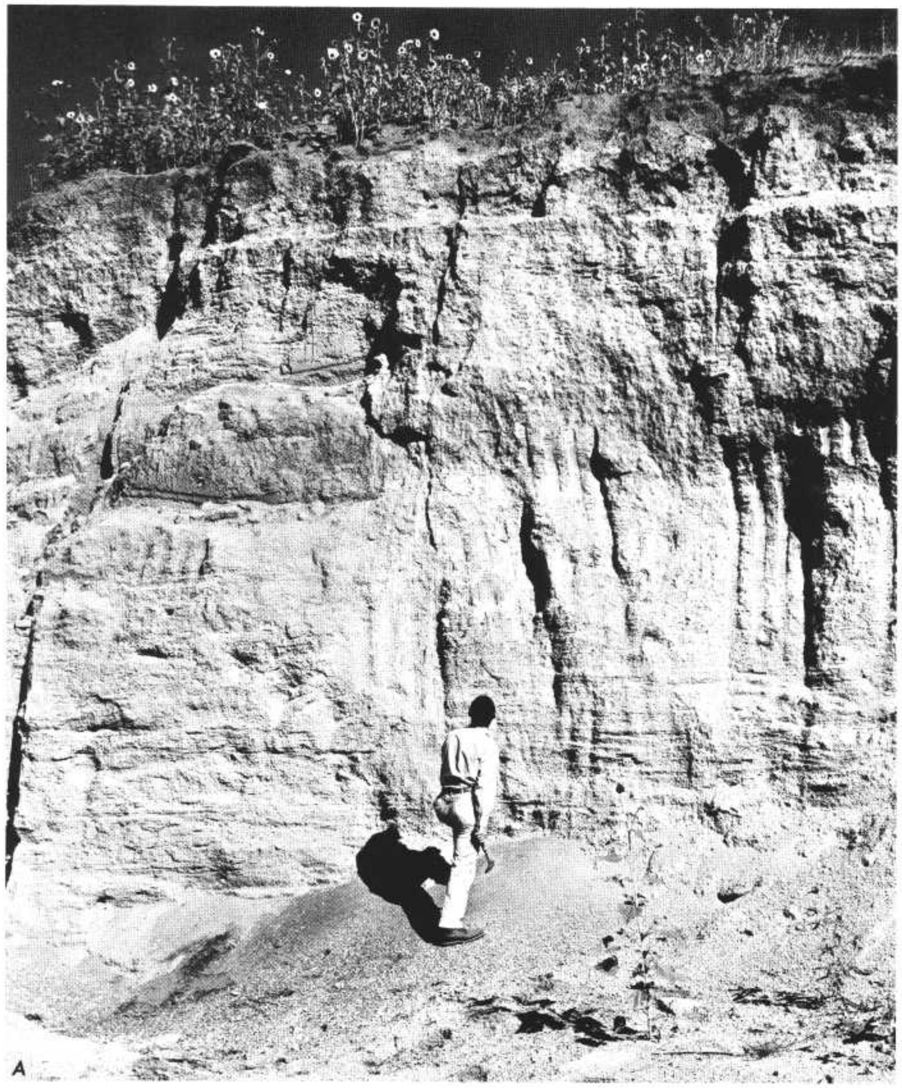
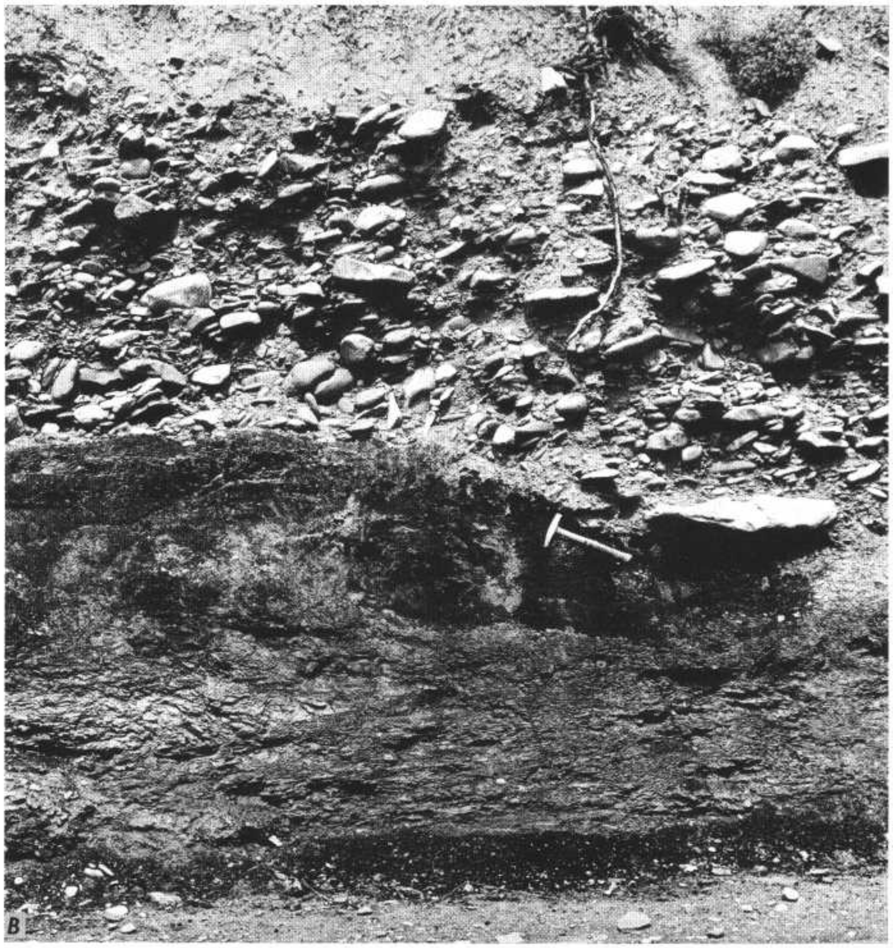


GRAVEL AND SAND: mementos of ancient floods. A, Excavation in clayey sand and pebble gravel on flood plain of Urraca Creek below the Stockade. B, Roadcut in gravel overlying coal and shale (Vermejo Formation) along lower Ponil Creek. (Fig. 22)

The bird that observed the landscape of Philmont flew on a zigzag course from east to west, from the plains to the mountains. In examining the rocks beneath the landscape, we will follow the same path, though, of course, more slowly.



Rocks beneath the plains

Gravel and sand

Rounded gravel and sand cap the plains around the Ranch headquarters and Cimarron town and also the long narrow flats along the larger streams in the mountains. On the plains and flats, the gravel and sand are mostly hidden by soil, but they can be seen wherever cuts have been made by streams or by man (fig. 22). Although there may be more sand than gravel, the sand makes poor outcrops, and it is easy to get the idea that the capping material is nearly all gravel. Natural and man-made cuts reveal that the gravel-sand blanket is usually only a few feet thick and that it lies mostly on soft black shale. Thin as it is, the blanket contains a vast amount of rock, for it covers 50 square miles on our map and many times that to the east.

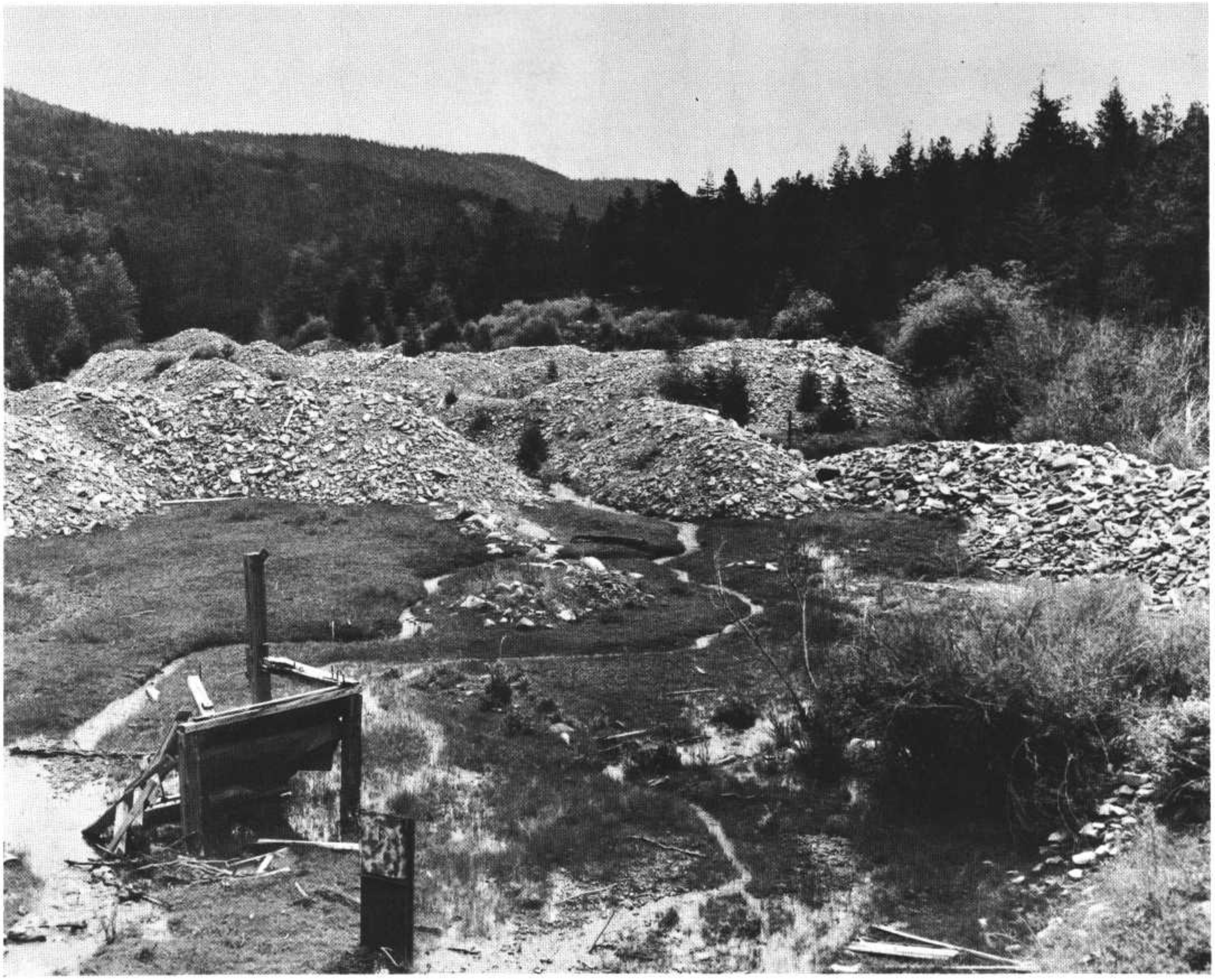
The gravel and sand on the plains are exactly like their counterparts in the beds of the creeks and surely formed in the same way: by settling out of flooding, shifting streams. Such deposits, which have settled out of running water—or out of any other transporting medium: lake water, sea water, wind, glacier ice—are called sediments. The plains beneath these sediments, then, are ancient stream flood plains. To build them must have taken a very long time, for the few floods each year can lay down only a little sand and gravel, and much or all of that may be swept away by later floods. How the sediments on the plains came to be high above the present streams is part of the story of landscape sculpture that will be told later.

Along Ute Creek, especially above Atmore Ranch, the gravel capping is not a smooth flat-topped soil-covered layer but stands in bare mounds as much as 20 feet high, so that the valley looks like a giant gopher prairie (fig. 23). The mounds are stream gravel that has been churned up by floating gold dredges. Gold was discovered in the gravel of Ute Creek late in the last century and has been mined intermittently ever since, both by dredges, when there was enough water to float them, and by hand methods. Several millions dollars worth of gold have been won from similar deposits on the west side of Baldy Mountain, near Elizabethtown, but the Ute Creek gravels were never very rich. In 1961, the rusted remains of the last dredge, long unused, still sat near the mouth of Ute Creek.

Miners who worked on Ute Creek still live at Cimarron. They say the gold was in flakes, chips, and small chunks lodged between the gravel stones; one nugget weighing nearly 12 ounces is said to have been found in the 1890's. The valley is about worked out, but gold "colors" can still be panned from the creek.

Like the stones of the gravel, the gold was washed off the mountains upstream. Because gold is so heavy, very small pieces settled out along with the coarse gravel, while the small bits of lighter minerals were swept on downstream as sand and mud. Such water-laid deposits of heavy minerals are called placers.

A large part of the world's gold production has come from placers.



GRAVEL MOUNDS made by gold dredges along Ute Creek. (Fig. 23)

The famous gold rushes of history started with the discovery of placer gold, for anyone can go placer prospecting with little money or knowledge; anyone with a mule or a gold pan and a little luck may make his fortune. In turn, many bedrock gold lodes have been found by tracing placer gold upstream to its bedrock source. (More often there is no rich source; instead, the gold is scattered in the rocks, and its richest concentration is in the stream gravel.)

Gold mining at Philmont went the other way, however. Gold, in veinlets and as thickly scattered specks, along with some copper and iron minerals, was found and mined high on Baldy Mountain in the 1860's; the first placers in the valleys below were discovered years later. For many decades both placer and bedrock mining came and went; at times a dozen mines were producing gold. During the great depression of the '30's, Baldy Town had a population of several hundred (fig. 24*A*); but as economic conditions improved, the miners left, and all the wooden buildings were moved. Today, nothing but a few stone ruins and mine dumps is left (fig. 24*B*).

Little is known about the bedrock ores. Written records are poor, and we have no first-hand knowledge; for when we were there all the mines on Baldy Mountain were caved in, flooded, or otherwise inaccessible. The mining areas, which are privately owned, are closed to visitors; this is just as well, for such mines are unsafe and should be avoided.

Gold is not the only heavy, tough, chemically resistant metal that is washed from sand and

BALDY TOWN. A, In 1939. B, In 1961. (Fig. 24)

gravel. Nearly all the world's production of platinum and tin comes from placers, as does much of the world's supply of diamonds and of other heavy precious and semiprecious stones such as rubies, sapphires, zircons, and spinels.

The main value of gravel and sand does not come from their rare and glamorous burden of heavy minerals. Gravel, of the right kind and quantity, is itself a major mineral resource. Around 700 million tons of gravel mostly for road construction, was produced in the United States alone in 1960 and had a value of nearly $700 million. This is many times the value of the United States' production of precious metals and jewels and of about the same order as the value of iron produced. By comparison, the United States produces only about 100 million tons of iron annually; however, since iron is worth much more than gravel, the total annual value of American iron is about $900 million.

The gravel at Philmont, though not much used yet, is a valuable mineral resource for the future.

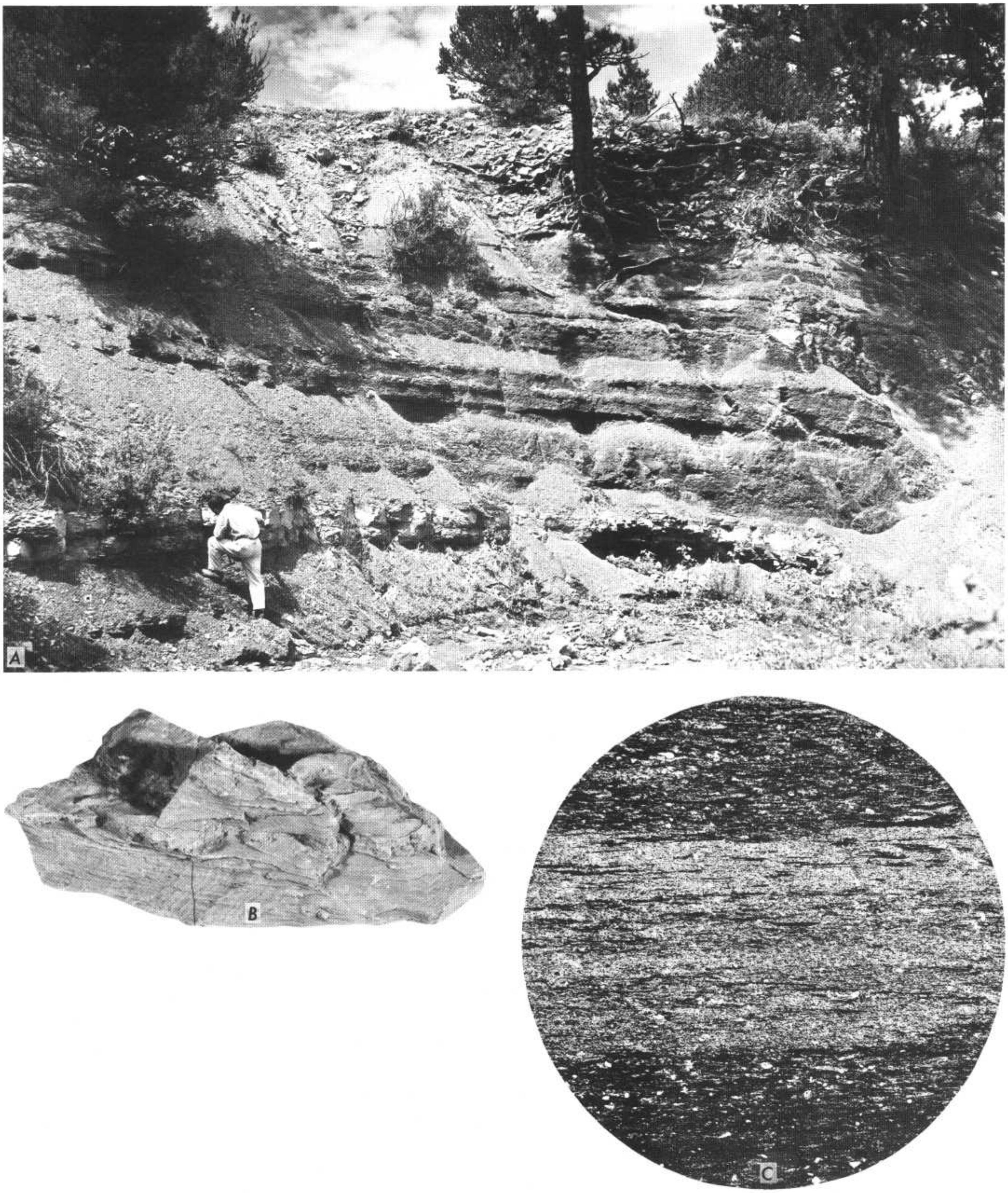
Black shale and orange shale

Beneath their blanket of gravel and sand, the plains are underlain mostly by dark-gray to black shale. This soft rock, which splits and flakes at the touch of a hammer, makes few ledges but appears in innumerable stream and road cuts. Good exposures, for example, can be seen in the banks of Cimarron Creek 1 to 2 miles upstream from Cimarron town and also on the main trail into New Abreu Base Camp (fig. 25). The fragments that make up most of this rock are too small to see, even with a pocket magnifier (fig. 25*B*); but when the rock is magnified enough (fig. 25*C*), it turns out to be made mostly of flaky plates of gray or brown clay and mica, tiny sharp-edged bits of colorless quartz, and black and brown clots of altered plant remains. Scattered in the rock are round white grains that once were single-celled living things called coccoliths. The shale began as mud—a sediment like sand and gravel but much finer grained. Now—dried, hardened, and compressed—its grains having been cemented together, it is rock. Such cemented sediments are called sedimentary rocks.

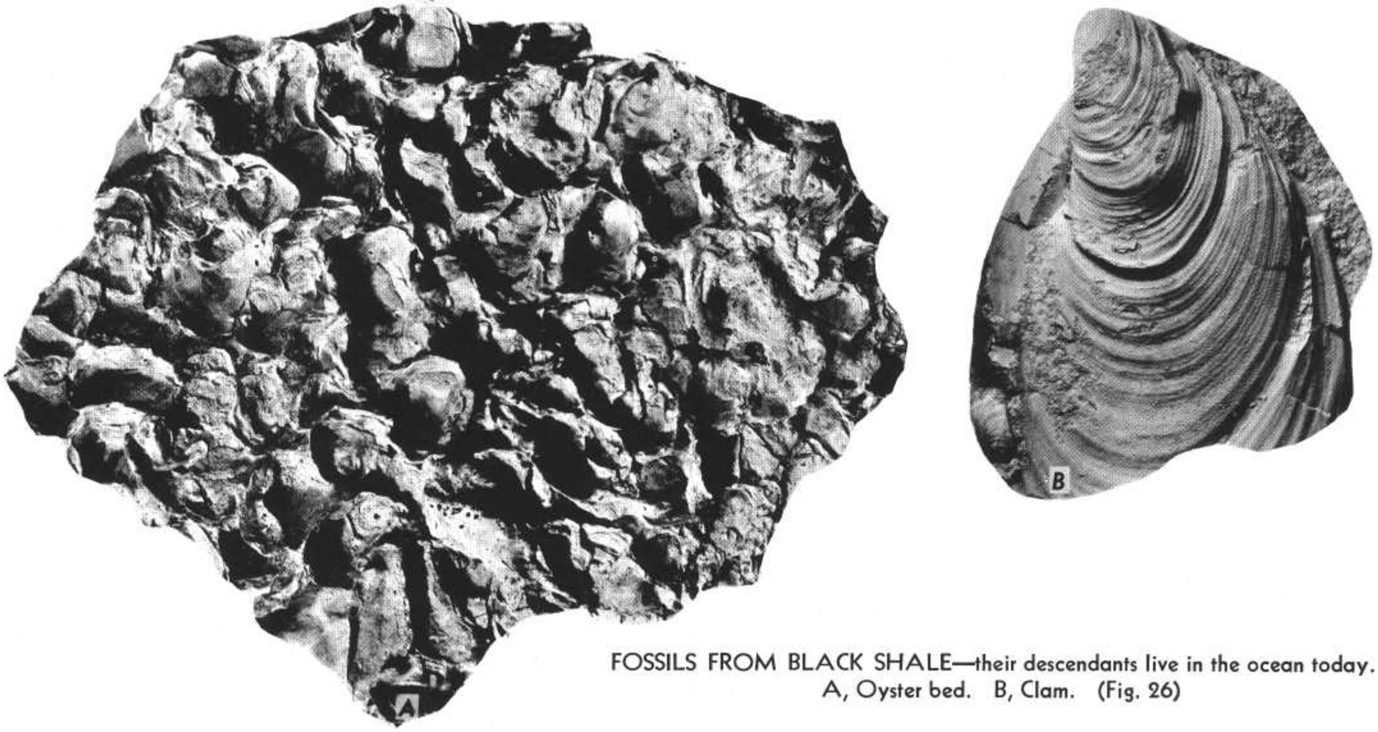
That life once flourished here when these rocks were mud is shown by more than microscopic fragments. In many places the shale contains the fossilized hard parts of many animals and the prints made by the hard or soft bodies of other animals that long ago decayed and vanished (figs. 26, 27, 28). The most abundant fossils, often encased in biscuit-shaped masses of orange-stained limestone, are shells. Most of the shells are of oysters and clams; some are smaller than a dime, and others are larger than a football (fig. 26). There are also the shells of many snails and of several types of extinct ammonites (distantly related to cuttlefish and squids); some are straight and shaped like a dagger sheath, some are tightly coiled, and all have marvelously complicated walls between the shell chambers (fig. 27). Quite different, and less common, are shark teeth—sharp incisors that have scalloped cutting edges like the edge of a bread knife, and stubby molars that have flat grinding surfaces (fig. 28).

These rocks are now much more than a mile above sea level and 600 miles from the nearest ocean water, but they began as mud on the ocean floor. The shale itself does not show this, for gray and black muds also form on stream floods plains or in lakes, as we have seen. Convincing evidence comes from the fossils. The snails and clams are of little help, as some snails and clams live in fresh water. But living oysters, sharks, and all relatives of the extinct ammonites live only in the ocean; and rocks which contain the remains of these animals must have formed in salt water. Some of the animals—the oysters and clams—lived and died where we find them. The ammonites and, of course, the sharks, were swimmers, and probably never lived in the mud; after the animals died, their hard parts settled down from above or were washed in. Muds like these are forming today in quiet waters along the Atlantic and Pacific coasts. We will soon learn how and when Philmont was beneath the sea and how and when it got so far from salt water.

Standing out from the black finely layered shale are a few beds of orange shale, generally no more than a few inches thick. When these are wet, they swell up and become sticky because part of their clay is the swelling type called bentonite. Some pure bentonite rocks when wet swell as much as 60 times their dry volume and have many industrial uses, but those at Philmont swell only a little. Though not very exciting to look at, these beds have an exciting history; for they are not simply muds swept into the ocean by streams wearing down the lands but are the remains of volcanic ash that blew into the sea from eruptions of distant volcanoes and mixed with other fragments settling to the bottom. Still visible under the microscope are the outlines of the original fragments of delicate volcanic glass, now changed to clay (fig. 29). The same dark shale formation has been traced over more than half

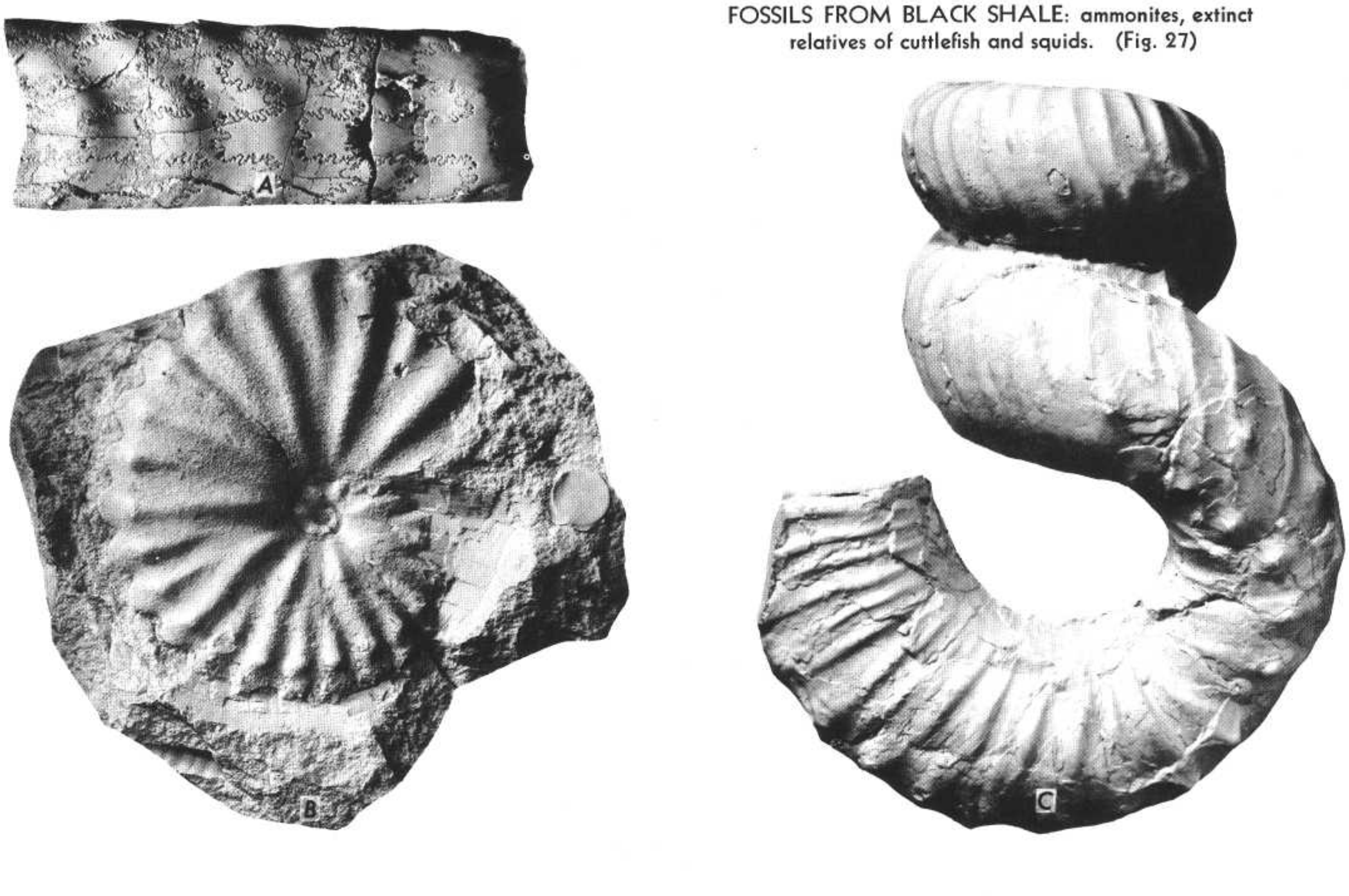


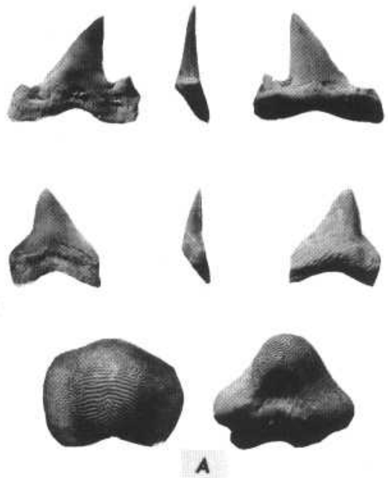
BLACK SHALE (Graneros Shale)—once it was mud on the floor of the sea. A, Bank of lower Urraca Creek. Light layers are limestone- B, Piece of shale, natural size. C, Slice of shale, magnified 30 times. This slice is cut across bedding and reveals the edges of three paper thin layers. The dull gray material is clay. The dark streaks are the edges of mica flakes and of plant remains. Bright sharp-edged grains. are quartz. A few round white grains are fossil organisms called coccoliths. (Fig. 25)



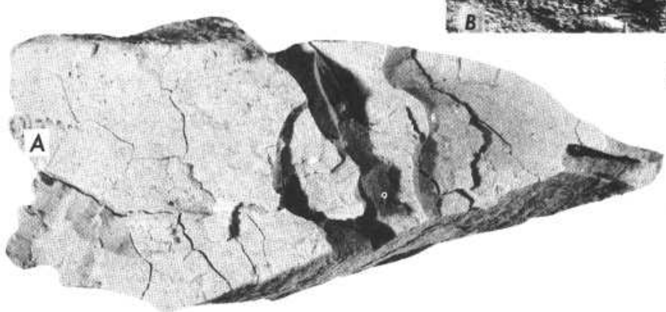
FOSSILS FROM BLACK SHALE—their descendants live in the ocean today.
A, Oyster bed. B, Clam. (Fig. 26)

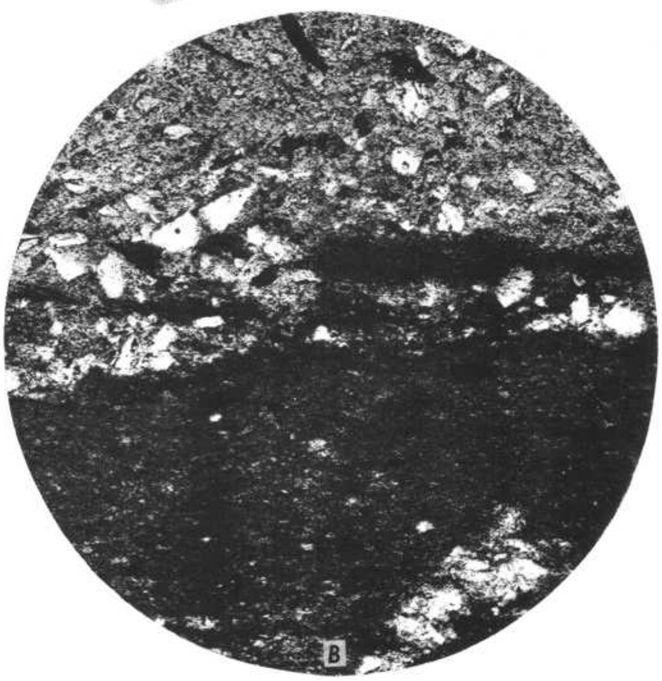
FOSSILS FROM BLACK SHALE: ammonites, extinct relatives of cuttlefish and squids. (Fig. 27)

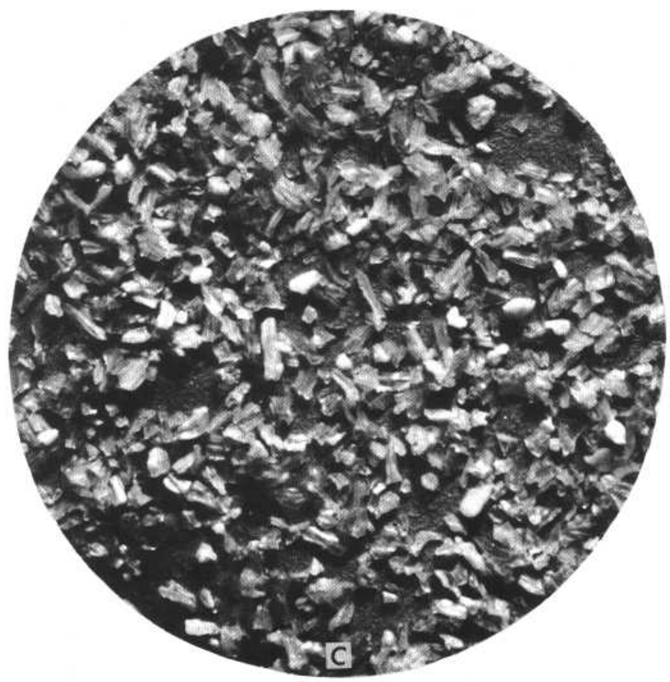




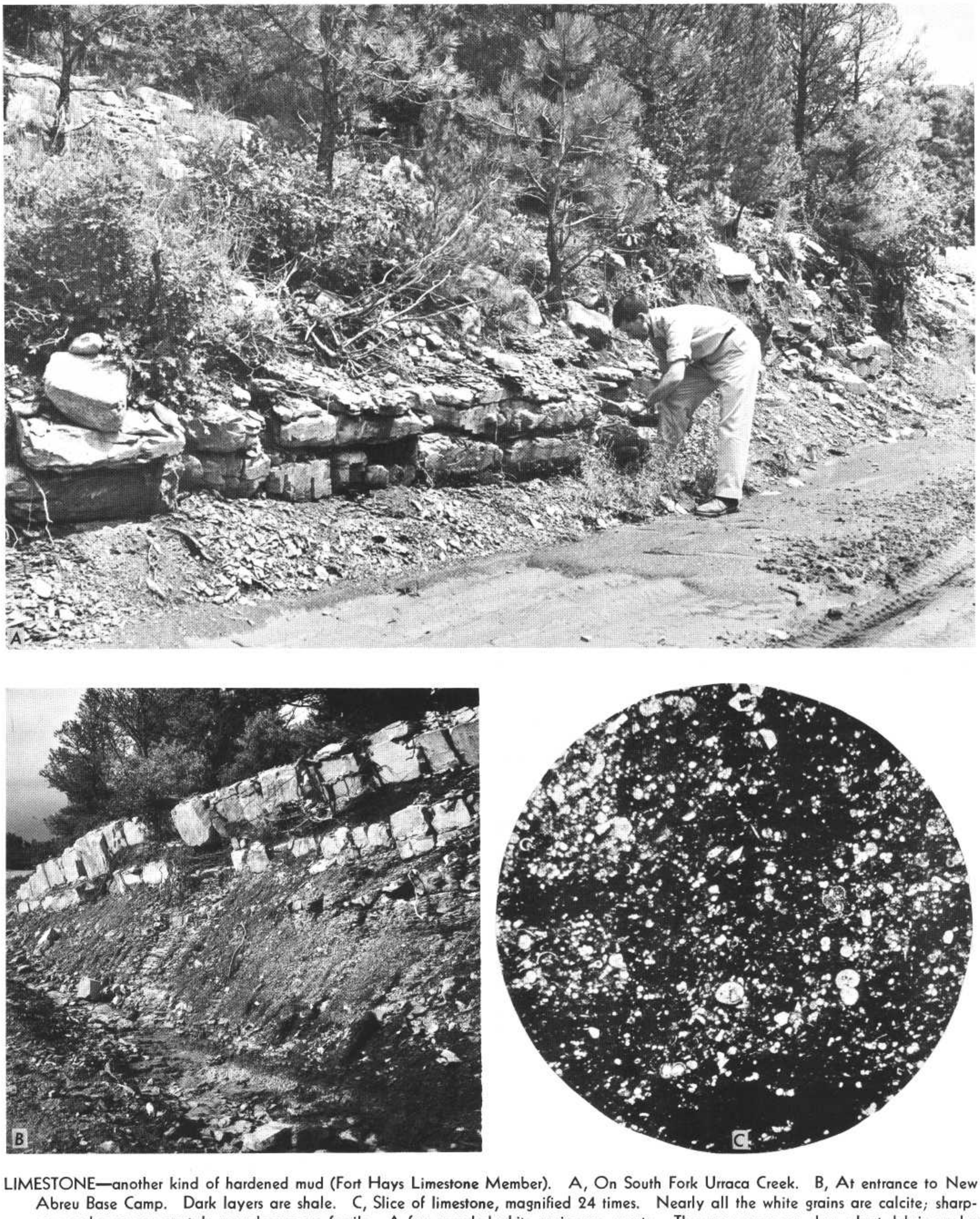
FOSSILS FROM BLACK SHALE (Pierre Shale): A, Shark teeth. Sharks have no bones. Instead, they have skeletons of soft cartilage, so only their teeth and, rarely, their fins are found as fossils. B, Fossils are often found in pods of limestone like this one, which is surrounded by shale. (Fig. 28)







ORANGE SHALE (from Pierre Shale). A, Piece of orange shale that swells when wetted because it contains altered volcanic ash. Natural size. B, Slice of shale containing much volcanic ash, now changed to clay; origin of ash revealed under the microscope by the shapes of its grains. Magnified 16 times. C, Unaltered pure volcanic ash from Montana magnified 5 times for comparison. (Fig. 29)



LIMESTONE—another kind of hardened mud (Fort Hays Limestone Member). A, On South Fork Urraca Creek. B, At entrance to New Abreu Base Camp. Dark layers are shale. C, Slice of limestone, magnified 24 times. Nearly all the white grains are calcite; sharp-cornered ones are crystals, round ones are fossils. A few rounded white grains are quartz. The gray areas are clay, plant debris, and a little mica. (Fig. 30) a million square miles in the interior United States and Canada. Everywhere, it has beds of altered ash like these. Thin as they are, they add up to many cubic miles of volcanic dust and tell of tremendous eruptions somewhere to the west. The volcanoes themselves, however, no longer stand, and nó remains of them have yet been found.

Gray limestone

Tan- or white-coated low ledges of gray limestone rise gently above the sand-gravel blanket in the plains south of Philmont Ranch Headquarters and stand out on the sides of several benches. Limestone can easily be seen along the north side of the trail along South Fork Urraca Creek above the turnoff to Stone Wall Pass (fig. 30*A*) and on the Rayado Creek Trail at the entrance to New Abreu Base Camp (fig. 30*B*). The rock, in beds a foot or two thick, seems very hard and tough, but it is readily broken with a hammer and easily scratched with any knife blade. Like the shale that is interbedded with it, the limestone is very fine grained. Through a microscope, the limestone is seen to be composed mainly of tiny grains of calcite surrounded by the same materials that are common in the dark shale—clay, mica, quartz, and organic debris (fig. 30*C*). (The limestone specimen in fig. 30*C* is very impure; other parts of the same layer are practically pure calcite in tightly packed crystals and pellets.) Here and there, as in the shale, are fossilized remains of oysters, clams, snails, and ammonites.

The limestone must have formed in somewhat the same way as did the shale—that is, as a sediment on the sea floor. But the calcite, unlike the clay, mica, and quartz, is not bits of older rocks washed in from the land. Calcite (calcium carbonate) is soft and is much more soluble than other common minerals in ordinary surface water (dissolved calcite is the main cause of "hard" water). Limestone does not, therefore, survive much stream transport or wave washing. So the calcite particles must have formed by some sort of chemical action not far from where they are now. Where inflowing streams and the activity of marine life supplied more calcium carbonate than the sea water could keep dissolved, some of the calcium carbonate was precipitated as crystals or as droplike groups of minute crystals to make a kind of calcite mud. Part of the calcium carbonate also went into the bodies of plants and animals, and fragments of these also sank into the mud. Later, the mud was buried by other sediments and was dried and compressed by their weight into limestone.

Limestone muds that may some day become rocks like these are forming in many parts of the ocean, where they are not diluted by too much debris from the lands—for example, in the shallow water on the Bahama banks, in the Pacific coral islands, and also at many places on the deeper ocean floor.

Dark mica-rich lamprophyre

Lamprophyre, a rare rock the world over, is fairly common on the plains of Philmont. It is best seen at the southern edge of Horse Ridge, 1.2 miles northwest of Scout Ranch Headquarters on the north side of the trail to Cimarroncito Base Camp (fig. 31). The lamprophyre in Horse Ridge is a coarse-grained greenish- to brownish-black rock that looks like it is made wholly of closely packed flakes of glittering brown biotite mica (fig. 31). Through a microscope, however, it can be seen that the rock actually is less than half biotite—part of it in large crystals, and part in small crystals—and that the rest is mostly small crystals of green pyroxene intergrown with the biotite and with a little magnetite and calcite (fig. 31). The grains of these minerals are not rounded, as they would be if they had been washed in by water, but have the sharp corners and edges of crystals. Packed tightly together, they look as though they all grew at about the same time, although the large biotite crystals may have had a head start. Besides having crystals instead of rounded grains, this rock contains no quartz or clay or organic remains like the surrounding shale or the limestone does. Furthermore, it is not layered in the shale but is a vertical sheet 6 to 8 feet thick that cuts across the bedding (see figs. 110, 116).

The lamprophyre is not a sedimentary rock that settled out of running or standing water. Instead, it rose as a thick hot melt from inside the earth and oozed into fractures in the already solid shale. Upon cooling, it crystallized like fudge or sugar. The blocks that show so well in figure 31*A* are the result of shrinkage due to cooling. Rocks of this sort, which cooled from a melt, or magma, are called igneous rocks. A very large part of the rocks at Philmont formed from the freezing of rock melts, but most of them are very unlike the lamprophrye in appearance and in mineral content. Most of them, however, are like the lamprophyre in having two generations of minerals—an earlier formed set of large crystals, called phenocrysts, held in a later formed base of smaller crystals or of glass, which is molten rock that cooled so quickly that no crystals had time to form. An igneous