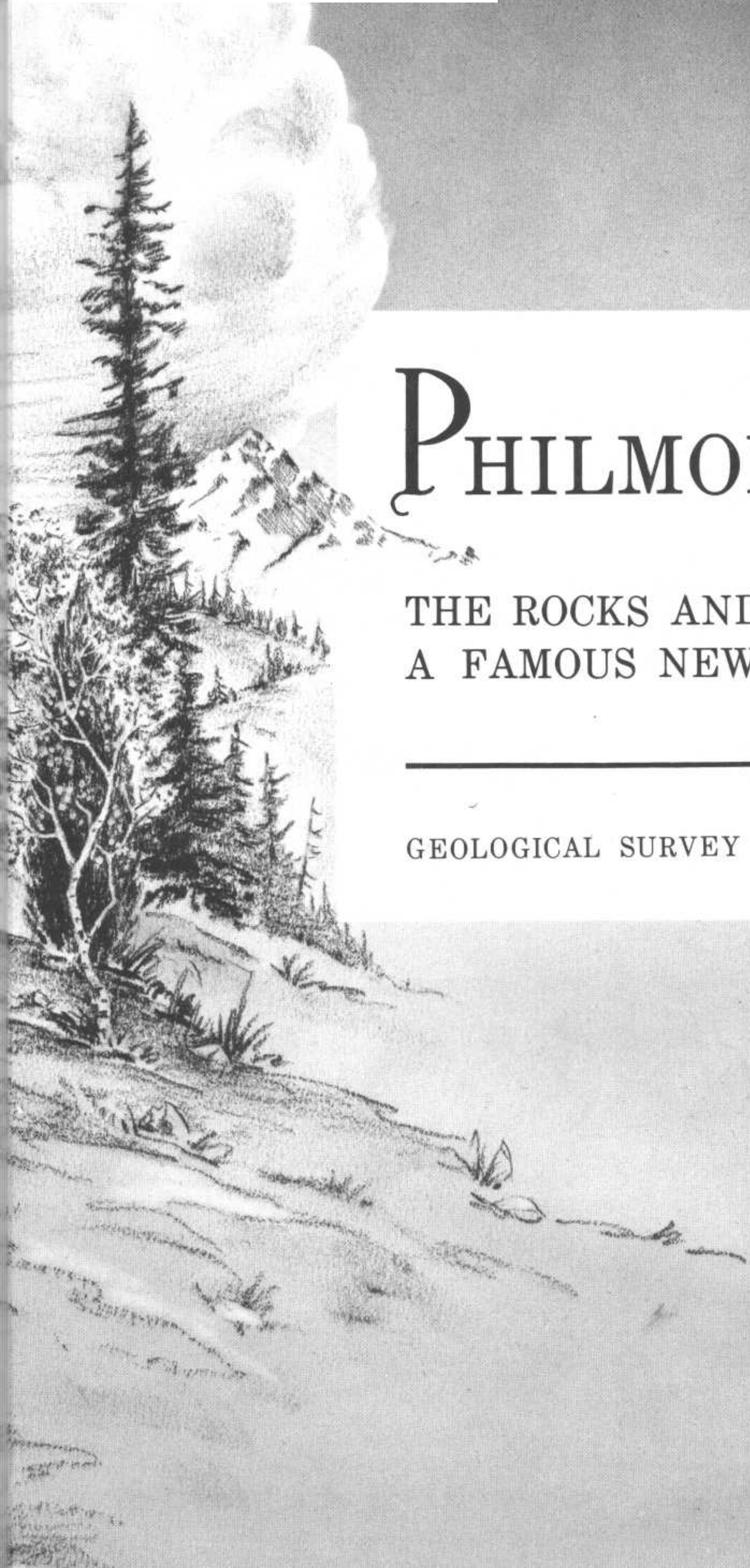


PHILMONT COUNTRY

THE ROCKS AND LANDSCAPE OF A FAMOUS NEW MEXICO RANCH

GEOLOGICAL SURVEY PROFESSIONAL PAPER 505

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

Deformed layers: Broken rocks

Folding explains many of the large-scale deformities we see or interpret in the rocks at Philmont, but not all. Some of the rocks were deformed by breaking. An example is in the north wall of Cimarron Creek canyon, 7 miles west of Cimarron town, or 5 miles east of Ute Park. Exposed for 500 feet is an abrupt repetition of formations that cannot be explained by tilting or folding, as the photograph and sketches of figure 105 show. Upstream and downstream from this place, the Trinidad Sandstone makes a conspicuous cliff, the lower half nearly white and the upper half marked by two broad dark streaks separated by a narrow lighter colored band (these streaks are made by oil that seeped out of the rocks and dried in the air). Below the Trinidad Sandstone are scattered dark outcrops of Pierre Shale.

In this place, however, there is a sharp break in the cliff; and the entire Trinidad, streaks and all, reappears more than 100 feet lower, badly fractured but recognizable, and has Pierre Shale exposed below it in the cutbank of the creek. The sandstone and the shale are in their normal sequence and have the same low northward dip as the rocks uphill, so the repetition of beds cannot be the result of folding.

A reasonable conclusion is that the Trinidad and the Pierre have been repeated by movement along a break in the rocks that is about parallel to the main cliffs and is between the cliffs and the cutbank, as shown in figure 105*C*. The block of rock near the highway has moved relatively down, and the block farther away has moved relatively up. This is not merely a landslide; if it were, the block near the highway, especially the soft shale, would be all broken up, and the surface of movement would come out into the valley. The rocks still have their bedding, however, and the surface of movement dips into the earth. What happens to the break upstream and down is concealed by slide rock and vegetation, showing that the movement happened long ago.

We know little of the dip or shape of the break itself, so it is drawn straight and vertical in figure 105*C*. It might as easily dip moderately to steeply north or south or be curved and have changing dip. Only vertical movement is shown in the diagram, but there may have been either a little or a lot of undetected horizontal movement also. This interesting structure is too small to show on the geologic map.

Such abrupt displacements are called faults. This curious usage of a familiar word dates back several hundred years. It reflects the early British coal miners' uncomplimentary feeling about such structures. These men found faults to be a great nuisance, as many of the coal beds they dug were displaced by faults, and searching blindly for the offset part was wastefully expensive. Rocks the world over are broken by faults, and the structures are still a nuisance, not only in mining but also in the construction of dams, roads, and buildings. Faults also have their virtues: some are channels for ground water; others are traps for gas or oil; and still others are the sites of ore deposits. Fortunately, modern geologists can determine the amount and kind of movement on most faults, predict their effect, and, where necessary, direct the search for offset parts. This is another reason why thousands of geologists are employed by industries and public agencies that work with the earth.

Faults come in all sizes, from barely visible movements to tremendous breaks that can be traced for more than a thousand miles and along which rocks have shifted for several miles vertically and for hundreds of miles horizontally. No really immense faults seem to pass through Philmont, but a variety of small and middle-sized faults has been found here.

A fault larger than that along Cimarron Creek but not quite so obvious runs close to the trail from Miners Park to Shaefers Pass (fig. 106). The evidence of faulting on Cimarron Creek comes from repetition of beds. Faulting near the Shaefers Pass trail is shown by the absence of expected beds—the Carlile Shale and, for a short distance, the Fort Hays Limestone Member. Dips toward the fault from east and west suggest that the rocks were first folded. The missing beds indicate that the rocks were then broken, so that a block of rocks on the east dropped down, or a block of rocks on the west rose up, about 500 feet; on North Fork Urraca Creek, Carlile Shale is faulted against dacite porphyry. Later, erosion stripped the uplifted younger rocks off the west block. Big enough to name, we call this the Shaefers Pass fault.

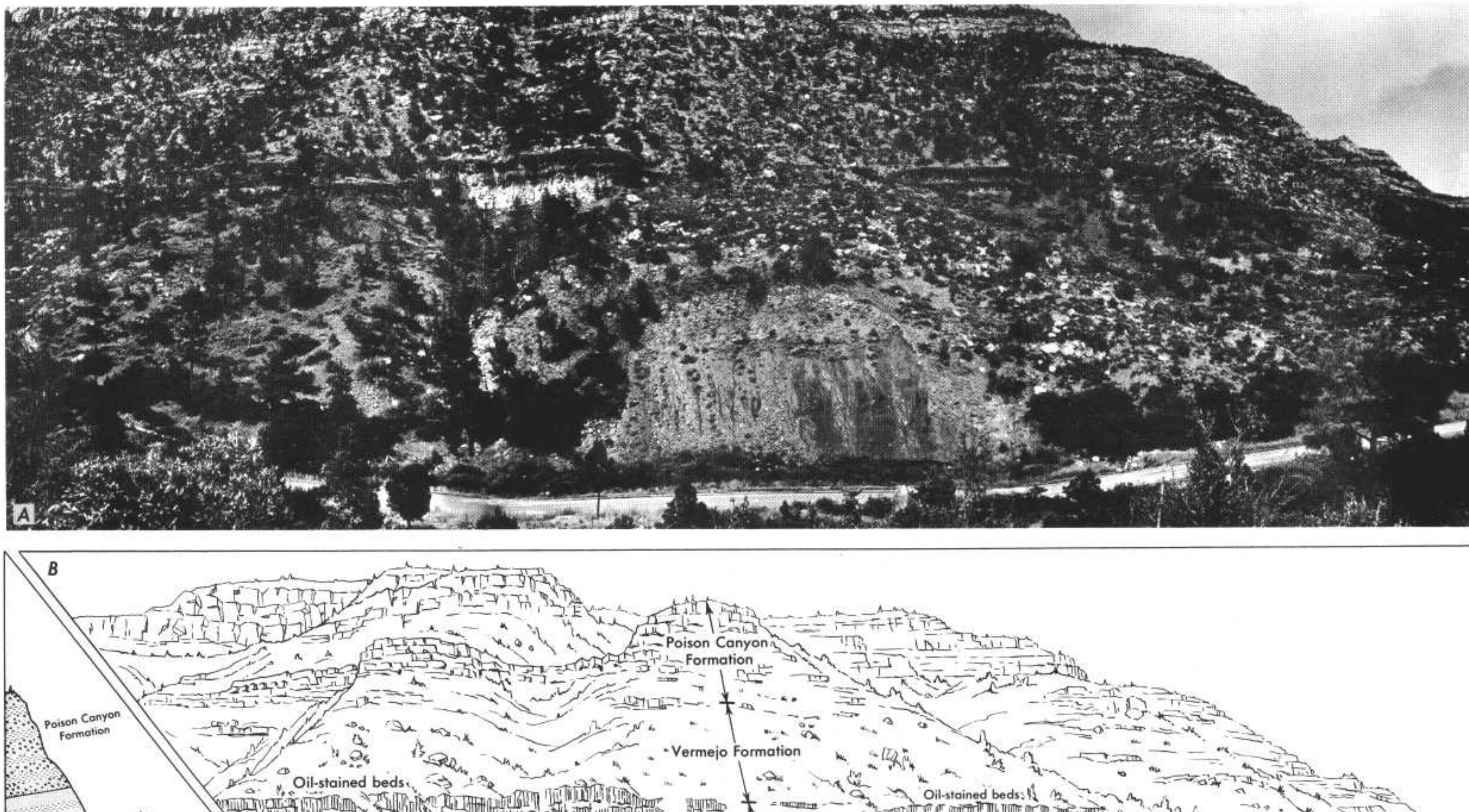
The fault itself is not exposed, and we can say little about its shape and dip; this is usually true of faults seen only on the surface. In figure 106A, the fault is drawn as vertical. If it dips eastward, as sketched in figure 106B, so that its sides, in effect, have pulled apart and the surface area has increased, it is called a normal fault. If the fault dips west, as in figure 106*C*, so that the sides are shoved together and the surface area has decreased, it is a reverse fault.

(Early geologists thought that most faults are the pull-apart kind and therefore called them normal faults. This is probably not so, but the names "normal" and "reverse" hang on.)

When did this fault happen? Had it moved hundreds of feet recently, the Quaternary slide rocks would be faulted too; and there would be a steep cliff, exposing shale and limestone, on the upthrown or western side. We conclude that the fault is not very recent, though it is, of course, younger than dacite porphyry, the youngest formation it cuts.

Signs of a much larger fault appear a mile west of the Shaefers Pass fault where the trail up South Fork Urraca Creek crosses the contact between Precambrian and sedimentary rocks (fig. 107). The Sangre de Cristo Formation, which is thousands of feet thick along Cimarroncito Creek to the north and along Rayado Creek to the south, is here reduced to but a few feet of broken rocks; the gneiss and schist at the contact are also broken and smeared out. Evidently, the contact is a fault.

Right on the contact is a zone a few feet thick of sticky dark clay containing scattered round boulders. The clay and boulders may

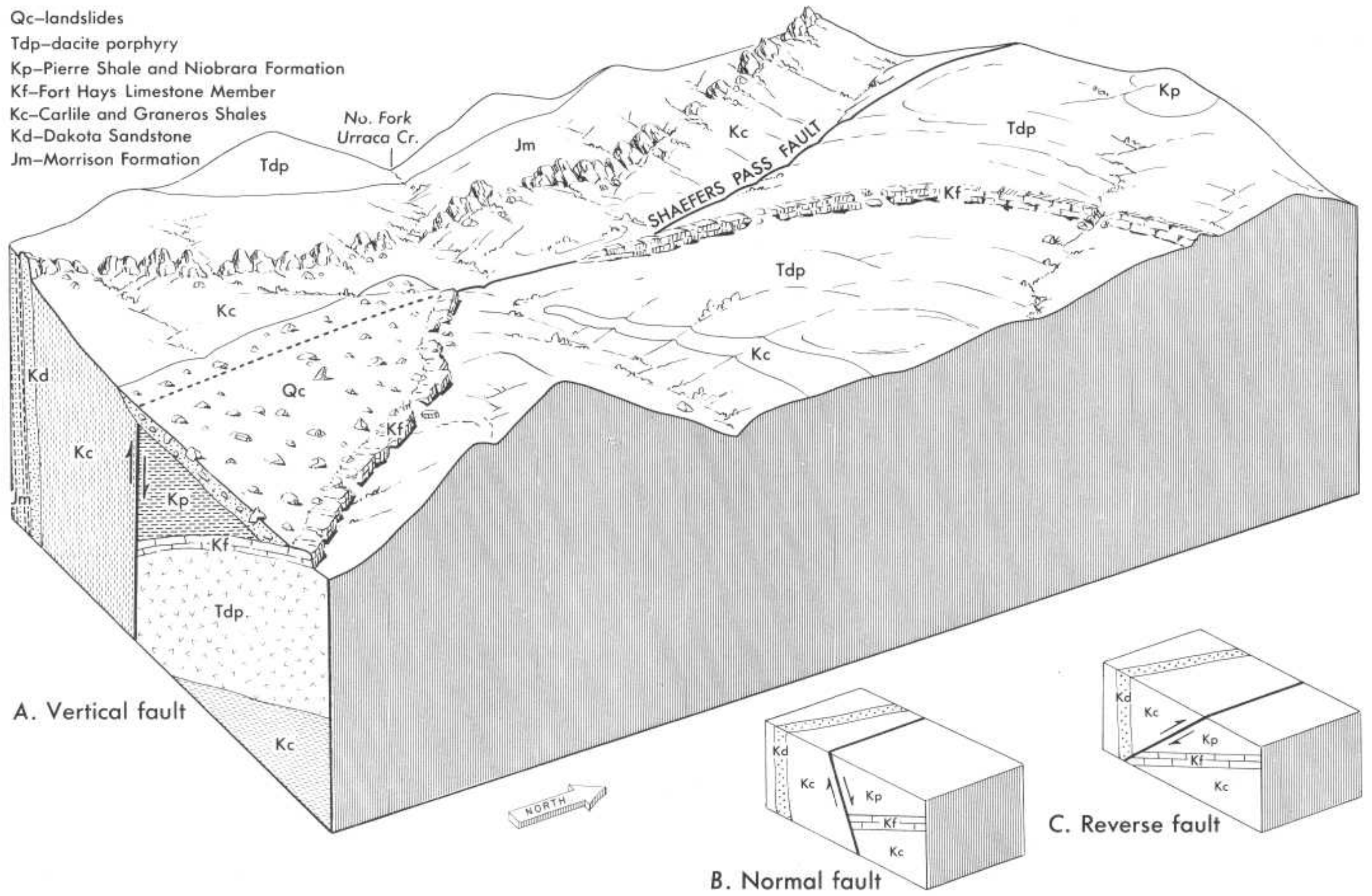


REPEATED BEDS along U.S. Highway 64. A, North wall of Cimarron Creek canyon. B, Sketch showing repeated beds. C, Slice through hillside, showing what happened. (Fig. 105) look like sediments, but they are not. The clay is soft wallrock that has been ground fine by repeated movement on the fault. The boulders are pieces of hard wallrock that have been caught up in the fault and rounded by abrasion but protected from further grinding by the clay. This outcrop does not reveal whether we are dealing with a normal, vertical, or reverse fault, but surely the mountain, or west, side has moved relatively up thousands of feet: the missing Sangre de Cristo rocks must have been eroded from the up side and must be below the surface on the down side.

To learn more about this fault, we must trace it beyond Urraca Creek. Doing so, we realize that it is a major feature, indeed. Southward, it continues without a break to Fowler Mesa. Covered by the lavas of Fowler Mesa and Rayado Peak, it reappears in Rayado Canyon and finally dives beneath the lava of Ocaté Mesa. It is responsible for the absence of Sangre de Cristo and Dockum rocks above Crater Lake Camp, and near Fowler Pass it cuts out the Entrada and Morrison Formations as well.

Near Fowler Pass are good exposures that give an idea of the dip of this fault. If the dip is vertical, the fault should go straight across hills and valleys alike, as do the vertical beds in figure 95*B*. If the fault dips east, it should bend downstream as it crosses the canyon north of Fowler Pass, as does a bed dipping downstream in figure 95*D*. Actually, the fault turns upstream (west), suggesting steep westerly dip, as does a bed dipping upstream in figure 95*C*. Crossing the canyon of Rayado Creek, the fault distinctly bends upstream, so we decide that it indeed dips westward. This means that older rocks have been shoved over younger ones, reducing the surface area. The fault is, therefore, a reverse fault. Its trend or strike is not the same as that of the formations bent up east of it, so that it cuts varying amounts of the formations which lie above the gneiss and schist. Because this structure is best seen near Fowler Pass, it is named the Fowler Pass fault.

The Fowler Pass fault has been traced for 16 miles across all of Philmont, as plate 3 shows; it probably continues for many miles



SHAEFERS PASS FAULT. A, Geologic diagram of area near trail to Shaefers Pass; fault shown as vertical. B, Drawn as though fault dips east; normal fault. C, Drawn as though fault dips west; reverse fault. (Fig. 106) beyond. For much of its length, the fault itself is obscured by dacite porphyry that has risen up along it.

The Fowler Pass fault was probably active in early Tertiary time. It is younger than the early Tertiary Poison Canyon Formation but older than the dacite porphyry and the basalt. If the Fowler Pass fault moved fast enough to make a cliff or scarp, the uplifted side was leveled by erosion before the basalt lava was poured out, as the base of the basalt is at the same altitude on both sides of the fault.

The west side of the mountain core of metamorphic rocks is also bounded by a steep fault. Like the Fowler Pass fault, this fault is so large that it is hard to see at any one place. We have named it the Lost Cabin fault, as it is well exposed only in the valley of Agua Fria Creek near Lost Cabin Trail Camp. It must be steep because it is so straight, but we do not know whether it is vertical or dips east or west. In the creek valley, rocks of the Sangre de Cristo Formation are dropped down on the southwest against gneiss and schist. As the thickness of beds cut out by the fault is not known, the amount of relative movement can only be guessed. It was surely hundreds of feet and may have been thousands. South of the valley, the fault is covered by unbroken basalt. To the northwest this fault forms the long sweeping smooth curve of the contact between basalt and metamorphic rocks, except where basalt crosses the fault in Wild Horse Park.

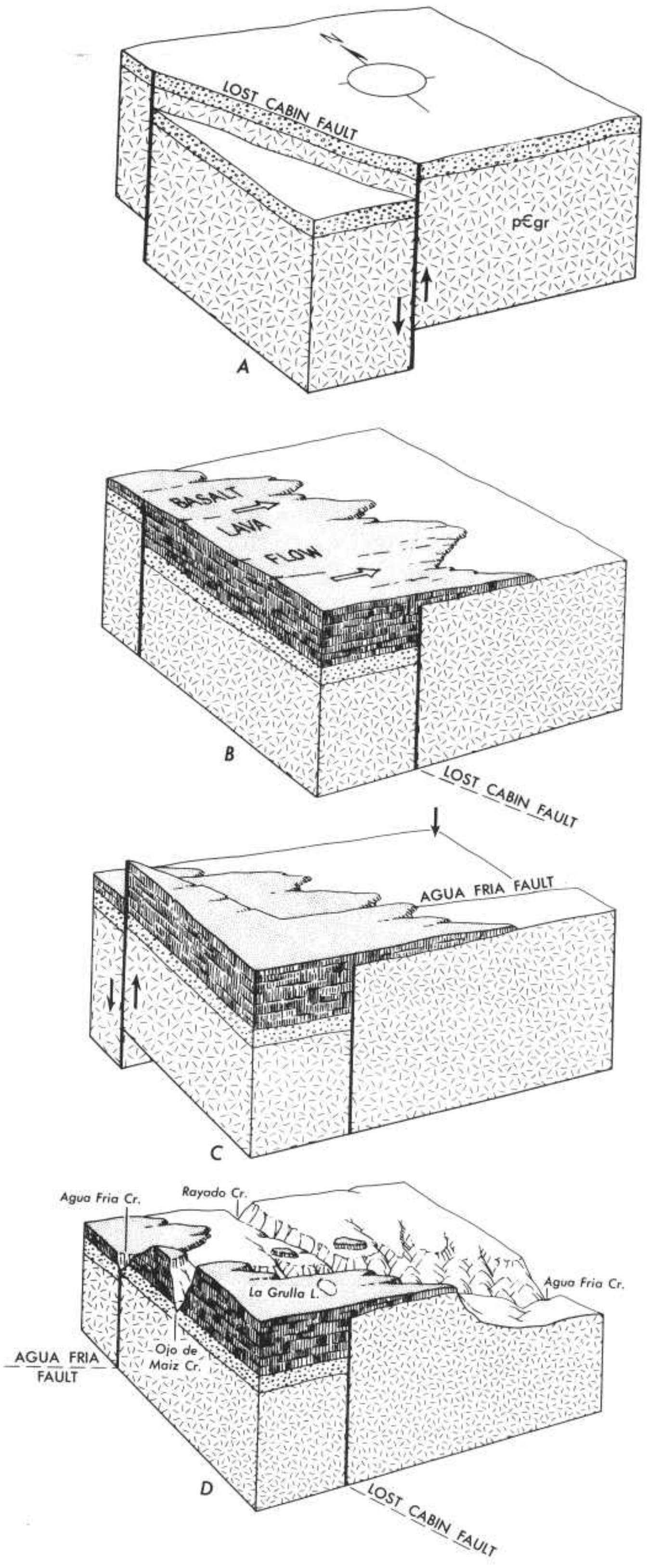
ZONE OF GROUNDUP SHALY ROCKS AND ROLLED BOULDERS on Fowler Pass fault between Precambrian gneiss and schist (off picture to left) and Sangre de Cristo Formation on right. South Fork Urraca Creek. (Fig. 107)

The Lost Cabin fault has some curious features that suggest a complicated history. Consider its relation to the basalt: is it younger or older? If the faulting is younger, the faultlike contact of basalt with metamorphic rocks on the north slope of Apache Peak makes sense, as does the general absence of basalt northeast of the fault: the basalt that once blanketed the upthrown (northeast) side was stripped by erosion, speeded up by uplift, which also wore away the original southwest-facing fault cliff or scarp. This sounds reasonable, but an equally reasonable story might go like this: Suppose that the fault were active long before lava was erupted and that the southwest-facing fault scarp acted as a dam to lava coming from a source to the south. The lava piled up against the scarp and flowed across the fault zone only where the cliff was low, as at Wild Horse Park. Continuing flow of lava near the source eventually buried the scarp on the south side of the creek. An added attraction of this reconstruction is that such a sequence fits the history of the Fowler Pass fault, and it becomes possible to think of the two faults as active at the same time, raising the core of metamorphic rocks and arching the overlying layered rocks.

But there was at least one more stage in the history of the Lost

Cabin fault, for still not explained is the low position of the peninsula of basalt east of the fault and on the north side of Agua Fria Creek. The base of this basalt body is more than 300 feet lower than the base of the basalt just across the creek to the southeast. Did the fault move again, but in reverse, so that the northeast side dropped down? If it did, why did not the basalt on the south side of the creek drop down too? We can perhaps solve this problem by noting that another fault runs east-northeast, roughly along the valley of Agua Fria Creek, for basalt on the hillside above Rayado Base Camp is also several hundred feet lower than basalt on the opposite canyon wall. Now we may imagine that a block bordered on the west by the Lost Cabin fault and on the south by the fault along Agua Fria Creek was dropped down a few hundred feet in the latest episode of faulting. The steps in this complicated reconstruction are shown in figure 108.

Having found one fault that seems to control lower Agua Fria Creek to its junction with Rayado Creek, we naturally ask if the valley of Rayado Creek downstream may not also be controlled by faults, for it has a zigzag path unlike those of other valleys to the north. No such faults can be seen between Rayado Base Camp and the foot of Rayado Peak, but their presence is strongly hinted by the fact that for miles the steep canyon walls are unbroken by any large side canyons although the walls of other large canyons at Philmont are deeply dissected. We reason that Agua Fria and Rayado Creeks may have cut their way rapidly downward in the crushed rocks along geologically recent faults, but that tributaries have not been able to do much cutting in the unbroken



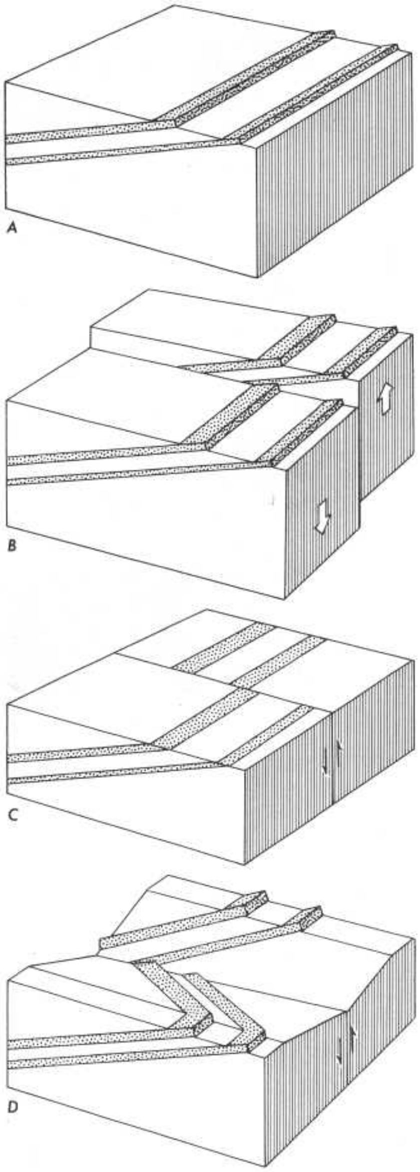
ONE WAY TO EXPLAIN THE GEOLOGIC STRUCTURE near the head of Agua Fria Creek. A, Birth of Lost Cabin fault. B, Erosion of sedimentary rocks from raised block, followed by lava flood. C, Birth of Agua Fria fault, south side up. D, Erosion of young fault zone to make Agua Fria valley. (Fig. 108) rocks on either side. If the zigzag faults exist at all, there is no reason to think that they are nearly as large or as old as the Fowler Pass or Lost Cabin faults.

Whether or not faults control any part of upper Rayado Creek, the Creek definitely runs along a fault zone for at least a mile upstream from Old Abreu Lodge. The sedimentary formations from the upper part of the Sangre de Cristo Formation to the lower part of the Graneros Shale, all of which here strike north-northwest and dip about 30° E., are interrupted at the creek. Unlike the Fowler Pass and Shaefers Pass faults, which run along the strike of the formations, this fault, the Abreu fault, cuts squarely across the strike, so that the formations are offset about 300 feet, strata on the south side having moved relatively northeast. Perhaps this displacement was due to horizontal movement of 300 feet, but the same result could have been reached with even less vertical movement, as figure 109 shows. Owing to the moderate eastward dip of the beds, the same apparent horizontal shift would result if the south side had been raised only about 170 feet vertically. Vertical movement also fits the displacement observed upstream, where the block on the south side of the Agua Fria fault has been uplifted a few hundred feet in a late episode of faulting.

So far, we have described mainly vertical movements on faults, though admitting that horizontal movement may have happened too. At least one steep fault at Philmont could have resulted only from horizontal shifting. This fault offsets the vertical sheet of lamprophyre on Horse Ridge, on the north side of lower Cimarroncito Creek. About 200 feet from its west end, the sheet is abruptly offset 7 feet, as figure 110 shows. As this is about the thickness of the lamprophyre, the north edge of the western part of the broken sheet now lines up with the south edge of the eastern part. This fault is far too small to show on the main geologic map, so a special enlarged map of it has been drawn (fig. 111).

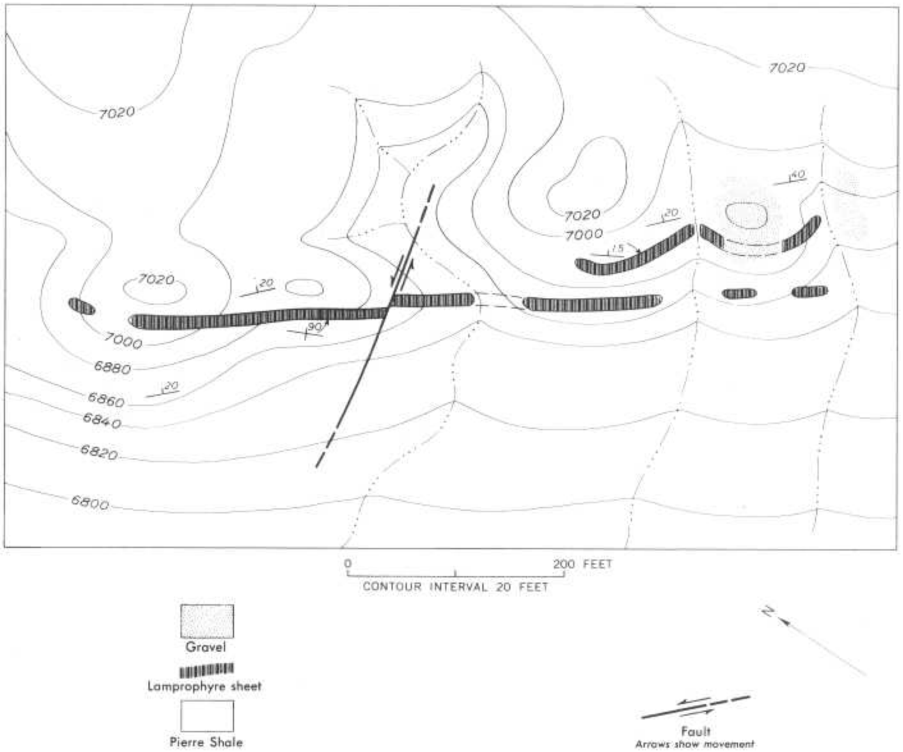
On the north side of Ponil Creek Trail 0.2 mile above the gaging station is a small but impressive example of still another kind of fault: a reverse fault that has very low dip (fig. 112). This fault, which dips 15° upstream, or northwest, has broken across at least three sandstone beds and a coal bed in the Vermejo Formation and has shoved these layers 17 feet southeastward along the fault, so that they are repeated in the roadcut. The hard sandstone beds have broken and moved cleanly, but the soft coal is contorted and dragged out where the fault crosses it. There is no way to be sure whether the upper rocks were pushed over the lower ones, whether the lower were pushed under the upper, or whether both sides moved a little. All we can be sure of is the relative movement, which consisted of telescoping or thrusting. For this reason, such low-angle reverse faults are called thrust faults.

Some of the world's great faults are thrusts in which plates of rock hundreds of miles long and thousands of feet thick have been shoved tens or even hundreds of miles over other rocks. The Rocky Mountain front for at least 350 miles in western Montana and southern Canada is a zone of thrust faults in which rocks as old as Precambrian have been thrust as much as 75 miles eastward over rocks as young as Late Cretaceous. Even larger thrusts are known in Nevada. The British Isles, and the Alps too, are riddled with huge thrust faults.

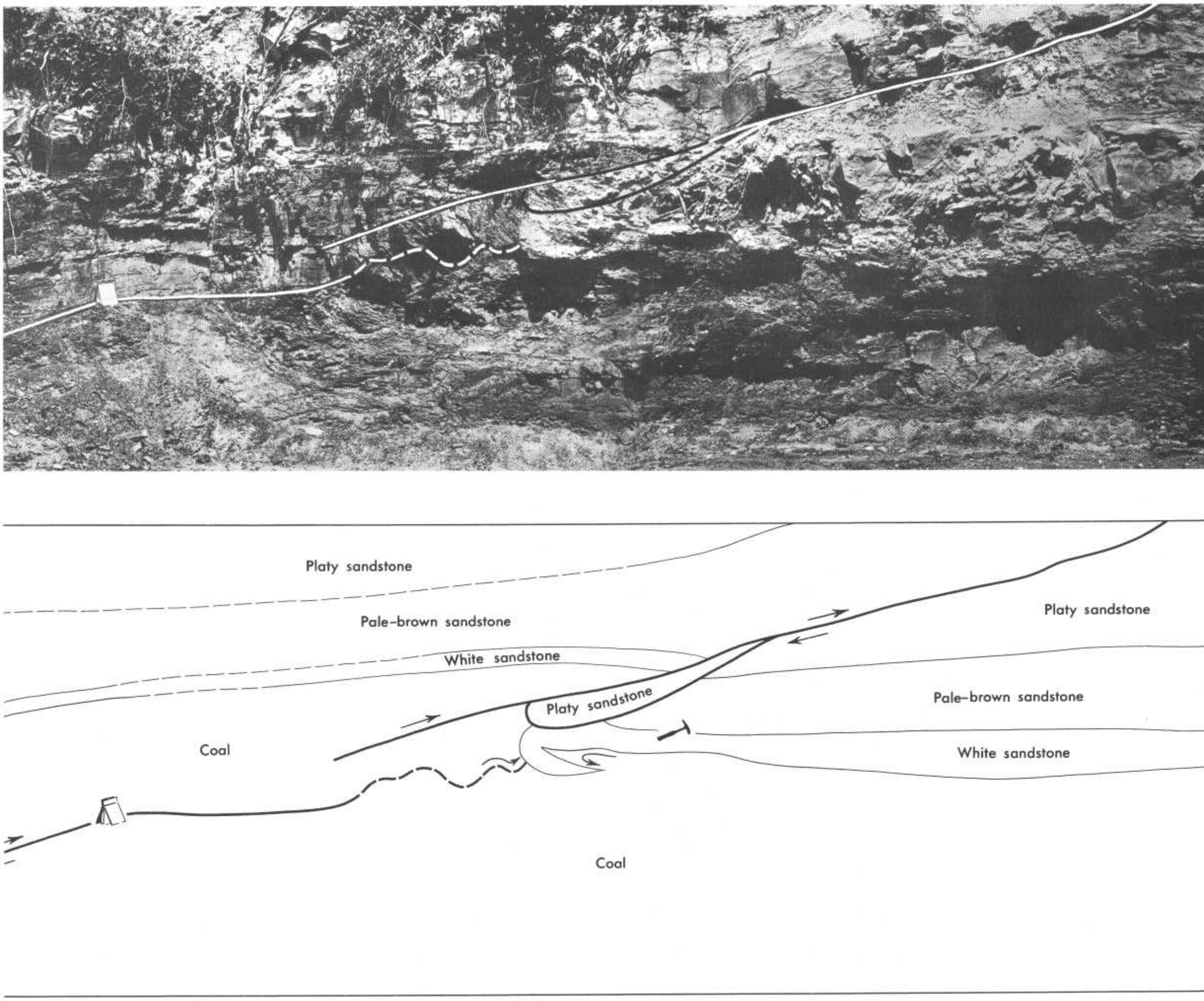


HORIZONTAL OFFSET OF DIPPING BEDS by vertical movement. A, Dipping beds before faulting. B, Vertical movement on steep fault that cuts across the strike. C, Erosion of uplifted side, leading to false appearance of horizontal movement. D, Stream canyon cut along fault, so that the V's formed by outcrops of beds now point downstream. This may have happened on the Abreu fault. (Fig. 109)

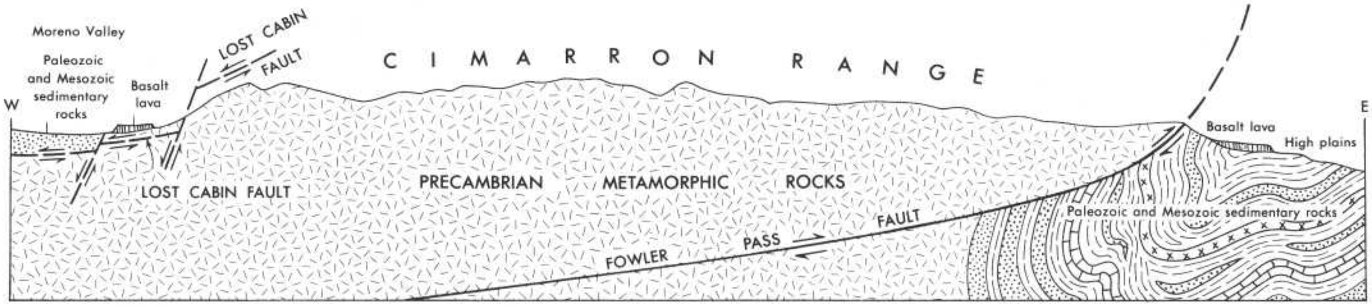
FAULT, along which movement was horizontal, cutting vertical lamprophyre sheet and moderately dipping Pierre Shale on Horse Ridge. Geologist is standing on the fault. The sheet has been offset 7 feet, which happens to be just about its thickness; the rocks on the left have moved toward the viewer, and those on the right, away. There may have been some vertical movement also, but because the sheet itself is vertical this cannot be detected. (Fig. 110)



GEOLOGIC MAP of lamprophyre sheet in Pierre Shale on Horse Ridge. Fault along which movement was horizontal is in center. (Fig. 111)



GENTLY DIPPING REVERSE FAULT, or thrust fault, on Ponil Creek Trail. (Fig. 112)



FOWLER PASS AND LOST CABIN FAULTS viewed as the sides of a giant plunger of Precambrian rocks thrust northeastward under what are now Moreno Valley and the Cimarron Range and exposed by later uplift and erosion. (Fig. 113)

Thrust faults are reverse faults that have a low dip, and some faults that are steep reverse faults at the surface flatten to thrusts at depth. Is it possible that the Fowler Pass and Lost Cabin faults are such concealed thrusts, having horizontal displacements of many miles, rather than steep reverse faults, having vertical displacements of a few thousand feet? Supporting this glamorous idea is geologic mapping in the Moreno Valley to the west (fig. 113). There the same Paleozoic and Mesozoic formations as are exposed at Philmont seem to be in faulted contact with the Precambrian crystalline rocks, and the fault surface seems to curve gently at shallow depth beneath the valley. One way to tie this surface to the contact of sedimentary and metamorphic rocks on both flanks of the Cimarron Range is to picture a giant plunger of Precambrian crystalline rocks thrust many miles northeastward under and partly through a blanket of younger sedimentary rocks and now exposed by uplift and erosion. There are other ways, however, to explain the field relations (see pls. 5, 6), and this bold thought must remain as just a thought until it can be tested by much more detailed work.

In a few paragraphs we have worked our way from a small unexciting fault on Ponil Creek to a sweeping idea that may or may not explain the general structural pattern of the entire Cimarron Range and its bordering valleys. The idea may not survive, but at least it shows what intriguing possibilities there are in applying geologic ideas, based on observation, to larger features whose full dimensions are hidden.

Large and old faults like the Shaefers Pass and Fowler Pass faults do not often advertise themselves. The actual break is usually hidden by fallen rock or by soil, and signs of movement such as scarps or offset stream courses are destroyed or are covered by deposits younger than the faulting. To recognize a fault takes thorough knowledge of the rock sequence and careful tracing of formations on the ground. The result is rewarding, if unraveling puzzles like this appeals to you, but the structure is usually not much to look at: it is too big to see without reducing it to smaller scale by mapping.

Two other faults that are too big to see are shown and named on the geologic map—the Beard fault, in the northern benchlands, and the Sawmill Canyon fault, along the mountain front west and south of Ute Park. Detailed mapping would surely reveal others. They are mostly steep faults that bend little as they cross rough country. None have had more than a few hundred feet of movement, so that only a formation or two is cut out or repeated.

On the map the relative movement on faults is shown by the letters "U" for up and "D" for down. Usually there is no way of knowing the actual movement with relation to a fixed surface, such as sea level. On some faults, both sides may have moved in the same direction but different amounts.

Without knowing how the rocks actually moved along a fault, we can figure out the offset of the two sides in several ways. A quick guess can be made by noting the thickness of formations that are cut out or duplicated by the faulting, taking their dip into account; this is the method we have been using in our discussion. A much better estimate can be reached by making a drawing to scale and measuring the offset. On most faults there is both horizontal and vertical displacement, so that the total movement is oblique.

Generally, the main movement on faults everywhere, as at Philmont, seems to be vertical. Nevertheless, tremendous amounts of horizontal displacement are known on some faults elsewhere, if not at Philmont. For example, the vertical San Andreas fault in California, which has been traced for at least 600 miles and may be much longer, seems to have had at least 30 miles of horizontal offset in the last few million years and as much as 400 miles of total horizontal offset since late Mesozoic time; never has it had more than a few hundred feet of vertical movement. The movements which add up to this startling displacement were not in a few gigantic shoves but in thousands of small shifts coming many years or centuries apart. One such movement caused the famous San Francisco earthquake of 1906 in which the maximum horizontal offset was 21 feet. Great total vertical displacements, too, are the result of many small movements rather than of single great ones; the largest vertical displacement known in a single fault shift was at Yakutat Bay, Alaska, where a part of the coast rose nearly 50 feet in 1899.

On some faults not even the relative movement can be learned. For instance, we cannot say anything about movement on the faults that border the mass of coarse-grained granodiorite near Clear Creek Store. That the borders are faults is plain for both the granodiorite and the metamorphic rocks are crushed and broken in a belt several hundred feet wide along each border; but without knowing the relation of the metamorphic rocks to the granodiorite before faulting, we have no way to tell how the faults moved. However they moved, they formed before the Sangre de Cristo Formation was deposited, as the Sangre de Cristo rocks lie across both faults and show no sign of disturbance. These faults are certainly no younger than Pennsylvanian and may well be Precambrian.

The metamorphic rocks are doubtless broken by many other faults that were active both before and after metamorphism, but we do not have the information to recognize and interpret them.

Philmont in three dimensions

Now that we have some idea of the main disturbances—the folds and faults—that affected the layer cake, we can start thinking of the geology of Philmont in three dimensions. This has been done in detail for three slices, or cross sections, across the region, roughly at right angles to the main structural trends, on plate 5 (in pocket) and in less detailed but more digestible form on the familiar block diagram (plate 6, in pocket). Because of vertical exaggeration, the dips of formations on plate 6 look steeper than those of the same formations on plate 5, which shows the same slices at natural scale.

These illustrations, especially cross section *C*, show vividly the broad anticlinal arch that is the main structure of Philmont and its oblong core of metamorphic rocks and granodiorite that has been dragged up the sedimentary formations on its flanks and punched through some of them. Beyond the core, the cross sections show the folds into which the solid sedimentary rocks have been bent: broad shallow ones in the Tertiary rocks, narrower and deeper ones in the older rocks.

The diagram and sections reveal the main unconformities, between the Precambrian rocks and the Sangre de Cristo Formation, between the Vermejo Formation and the Raton Formation, between the Poison Canyon Formation and the loose Quaternary deposits, beneath the basalt flows, and between the basalt and the loose Quaternary deposits.

Displayed, too, are the relations of the porphyritic igneous rocks. Sheets of them invade the metamorphic rocks of the mountain core, follow some of the faults, and spread through the sedimentary layers, both along and across the beds (more about these later). Visible also is a generation of steep faults that break through the complex of sedimentary layers and igneous sheets; some of these faults no doubt served as conduits through which the basalt lava rose to the surface.

Reviewing what we have seen of folds and faults and what we have reasoned about them, we realize that at Philmont they are not scattered at random but have a fairly clear pattern in space and in the fourth dimension, time. The rocks beneath the plains are gently folded and are broken only by small faults distinctly younger than the folds. The intensity of folding and faulting increases toward the mountains and is at a peak near the contact between Precambrian metamorphic rocks and the much younger sedimentary and igneous rocks. Here, also, faulting is younger than folding, but probably not much younger.

Two main times of deformation are evident: one, about which we know little but suspect much, in Precambrian time; the other, spread over a long fraction of Tertiary time after the Poison Canyon Formation was laid down but before the basalt lava poured out. Only a little faulting and tilting has come after the lava.

No movement has occurred on any of the faults since the region has been settled and probably not for many hundreds or thousands of years. Earth movements convulsive enough to break the ground are accompanied by major earthquakes. Neither history nor legend reports any great quakes in the Philmont region, nor are there any fresh signs of movement—such as scarps, long sag ponds, or offset streams—along known faults.