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BAKED ROCKS

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Abstract

Metamorphic Rocks are either igneous or sedimentary rocks whose texture, composition or appearance has been altered by heat and/or pressure. This process is called metamorphism. Any one, or two or more characters may be affected. Examples of metamorphism are: limestone changed to marble, sandstone to quartzite, shale to argillite, and granite to gneiss. This article describes some metamorphic observations in Colorado. It is written as a field guide.

The Exposures in the Purgatoire Valley, Colorado

When leaving Trinidad, Colorado, via State Road 12, driving westward, one passes through the Purgatoire Valley toward the Sangre De Cristo Mountains. Along the way one encounters a series of formations dipping gently towards the east. However the dip is so gradual that the formations appear to be lying horizontally.

The pertinent generalized geologic section of this area is given in Table I. It shows the sequence as well as the nature of the formations encountered. Some consider the Apishapa shale and the Timpas limestone to be equivalent to the Niobrara formation of the Cretaceous period. This outcrops in Kansas and other adjacent areas west of the Missouri River. Furthermore, all of the Tertiary deposits in this area are often lumped together as part of the Raton formation.

As one proceeds westward up the valley, some formations are exposed in the canyon wall. The sequence listed is from the surface downward. The uppermost, at the city's western border, is the Pierre shale, followed by the Trinidad sandstone.

About three miles out of town, one can see the Trinidad-Vermejo contact on the right (north) wall. Then after traveling approximately another 5 miles, the first Vermejo-Raton contact can be seen in the railroad cut on the right (north). The Raton formation then can be followed for the next 25 miles.

About five miles out of town, coal seams begin to appear in the Raton formation (Figure 1). Unconformities and sandstone lenses (channels) also can be seen intruding into the Raton formation in the road cuts to the north.

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After traveling about 10 miles west of Trinidad, one can identify numerous channel sandstones in the Raton on the right. About 16 miles out of town, a basalt sill intruding into the coal seam can be observed in the road cut on the right (Figure 2). Since this intrudes into the coal, the coal has been baked and altered to natural coke. This phenomenon can be seen plainly when one examines the basalt and coal contact at close range. The cooling rate of the basalt must have been rapid enough to produce a fine-grain aphanitic texture. A slower cooling time would probably have resulted in a coarse grain phaneritic texture with possible phenocryst formation.

About 20 miles out of Trinidad there is a railroad crossing over the Colorado and Wyoming Railroad. This line runs from a connection with the Santa Fe in

Figure 1. The Raton formation: a coal seam is shown at the top.

Table I. Generalized Geologic Section

Unit	Age	Description
Alluvium	Q	Unconsolidated, heterogeneous gravel deposits of the Cuchara Creek drainage system.
Lower level alluvial deposits and upland valley flats.	Q	Fine grained, unconsolidated, alluvial sediments on pediment surfaces and upland valley flats.
Upper level gravel	Q	Heterogeneous unconsolidated sediments containing boulders as much as 25 cm. in diameter.
		unconformity
Cuchara sandstone	E	White to pink, medium to coarse grained sandstone (ss) and some conglomerate (cgl)
		unconformity
Poison Canyon formation (fm.)	E	Yellow micaceous shale, fine to coarse grained, yellow arkosic ss., becoming white to pink in middle part, and boulder cgl. in upper 800 m.
Raton fm.	E	Coal, etc.
		unconformity
Vermejo fm.	K	Medium grained, gray, arkosic ss. coal and gray to black carbonaceous shale
Trinidad fm.	K	Massive, medium-grained, yellow to gray ss. in upper half, becoming thin-bedded and containing shale breaks in lower half.
Pierre shale	K	Brown shale.
Apishapa shale	K	Thin-bedded gray calcareous shale.
Timpas limestone	K	Blue-gray limestone (ls.) shaly in upper levels.
Carlisle shale	K	Brown shale becoming blue-gray in middle part capped by medium-grained brown ss.
Greenhorn limestone	K	Thin-bedded blue-gray fine grained ls. containing *Inoceramus* fossils.
Graneros shale	K	Brown shale, gray towards base.
Dakota sandstone	K	Medium grained white to yellow ss.
Purgatoire fm.	K	Shale and ss. in the upper members, and ss. and cgl. in the lower members.
		unconformity
Morrison fm.	JR	Red and green shale and compact gray ls.
Sangre de Cristo	P	Red and maroon arkose and sandy shale.

Q–Quarternary K—Cretaceous E—Eocene P—Permian JR–Jurassic

Trinidad to the Allen Mine up the Purgatoire Valley. This mine is an operation of the Colorado Fuel and Iron Company located in Pueblo, Colorado.

About 53 miles out of town is the junction of State Road 12 and State Road 111. State Road 111 turns left into the Tercio Anticline, also known as the Whiskey Creek Anticline. State Road 12 continues east.

On State Road 12, about 54 miles beyond Trinidad, the road passes through a gap in what mistakenly might be considered a dike. However, close examination of the rock face reveals that instead of an igneous intrusion, it is a resistant member of the Dakota sandstone. This bed has been tilted 90° to form a vertical wall. Locally the community is known as Stone Wall, Colorado (Figure 3).

Shortly after passing through the gap, the road turns to the right, following along a nearly vertical wall

Figure 2. A basalt sill intruding into a coal seam.

composed of the Sangre de Cristo formation. The white sandstone found below the Dakota and Sangre de Cristo on the right is the Entrada sandstone. Ahead to the north is West Spanish Peak.

To the right is Monument Lake, named for the upthrust rock in the body of the lake. When one turns right into Monument Lake Park and on the left (north) several basalt dikes intruding into the Pierre shale can be seen. The contact of basalt and shale is a layer of argillite. This is a metamorphic rock formed by the baking of the shale. This phenomenon will be found repeated at several places along the road. The dike

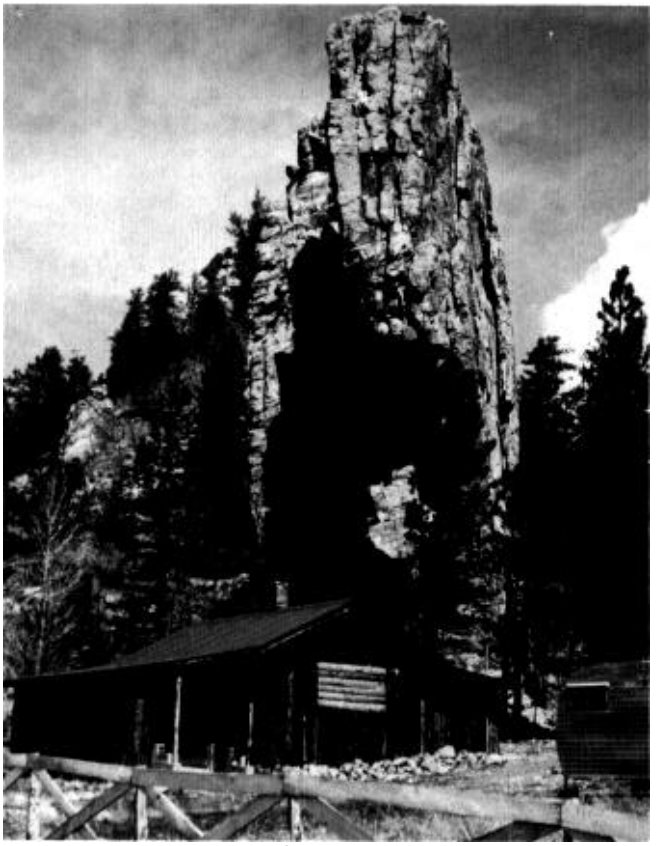

Figure 3. Vertical sandstone formation in Stonewall, Colorado.

Figure 4. Cobble formation.

that is the source of the baking has radiated out from the magma pool associated with the Spanish Peaks.

In numerous locations in this area, there is an interesting variation in the weathering of the basalt in several of the exposures. In some of the faces, the normal weathering of the face gives rise to some general debris which falls to the base of the exposure. However in others, a criss-cross pattern of vertical and horizontal fissures develops, that gives rise to a rounded type of cobble formation (Figure 4). The cobbles then fall to the base. General examination fails to reveal any obvious variation in the basalt.

Return to State Road 12. Turn right and continue north. Cross over Cuchara Pass and continue north along Colorado State Road 111. About 83 miles out of Trinidad, the feature known as Devil's Staircase is observed ahead to the north as a series of giant steps crossing the road. When alongside this feature, it is observed to be a large dike that extends almost to the road.

A few meters past the Devil's Staircase are what appear to be two dikes relatively close together. However, close examination will reveal that in reality these are two resistant sandstone ridges. Each has been metamorphosed from sandstone into quartzite by the heat of the intruding basalt dike in between them (Figure 5). The result is the superficial appearance of a pair of dikes that are close together. However, examination reveals that the material separating them is weathered basalt. The 'dikes' are actually metamorphosed sandstone! The appearance of the resultant weathering indicates that the quartzite is more resistant than the basalt.

General Thoughts

The location of the basalt sill suggests that it is post-Raton time, given that the basalt intrudes into the Raton stratum. Certainly the picture of the basalt intrusion into a soft coal seam, metamorphosing the coal but leaving the seam otherwise in place is a bit challenging.

This whole area lies within the general vicinity of the Spanish Peaks. That is why this region provides a wealth of opportunities to study various volcanic features such as dikes, sills, and plugs, as well as other volcanic phenomena. Dikes are so plentiful that the term "dike swarms" is used to refer to them. Obviously in addition, the peaks themselves provide for a good

Figure 5. Basalt dike between quartzite dikes.

deal of fascinating study. The several weathering patterns associated with the argillite formation are also interesting.

The case of the double quartzite dikes in the vicinity of the Devil's Staircase demonstrates a need for caution in drawing conclusions from superficial appearances.

Although desolate country, particularly in the dry season, I have found it to be extremely fascinating and certainly worthy of detailed study. After leading classes there for some 12 years, I never tired of visiting the area. I had planned to return and do some detailed study after retirement. Unfortunately the opportunity never materialized.

When I was a boy I believed that 'Darwin discovered evolution' [but] in Keats, in Wagner's tetralogy, in Goethe, in Herder, the change to a new point of view had already taken place. Its growth can be traced far further back in Leibniz, Akenside, Kant, Maupertius, Diderot. Already in 1786, Robinet believed in an 'active principle' which overcomes brute matter, and *la progression n'est pas finie.* For him, as for Bergson or de Chardin, the 'gates of the future are wide open.' The demand for a developing world—a demand obviously in harmony with the revolutionary and the romantic temper grows up first; when it is full grown the scientists go to work and discover the evidence on which our belief in that sort of universe would now be held to rest. There is no question here of the old Model's being shattered by the inrush of new phenomena. The truth would seem to be the reverse; that when changes in the human mind produce a sufficient disrelish of the old Model and a sufficient hankering for some new one, phenomena to support that new one will obediently turn up. I do not mean at all that these new phenomena are illusory. Nature has all sorts of phenomena in stock and can suit many different tastes.

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