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TONSTEIN OCCURRENCES IN THE RATON COAL FIELD, COLFAX COUNTY, NEW MEXICO

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INTRODUCTION

Tonstein (from the German; literally translated as "clay-stone") partings are well known to European coal geologists. Williamson (1970, p. 119) defined them as:

> .. dense mudstones containing kaolinite aggregates and crystals within essentially similar matrices. Usually occurring as thin beds less than 6 cm, they are typically developed in the coal measures facies. Although rare, they are of widespread distribution and form isochronous correlative horizons which have been extensively utilized in the European coalfields."

Tonsteins have not been widely recognized in American coal strata, and only sparse reports of their presence have appeared in geologic literature of this country. The first American worker to describe a tonstein parting in coal in the western United States was apparently Rogers (1914), although he did not identify it as such. Much later, Hoehne (1959) discussed some tonstein-like partings found in North America. Seiders (1965) pointed out the similarity between a flint clay parting in the Fire Clay Coal Bed in eastern Kentucky and European tonsteins, and ascribed a volcanic origin to the former. Asquith (1968) noted the presence of large vermicular kaolinite crystals in a clay parting associated with coal in the Almond Formation (Upper Cretaceous) of Wyoming, but Williamson (1969) was the first to point out that this occurrence was probably a tonstein.

Recently, tonsteins have been discovered in many Cretaceous and Tertiary coals of the Rocky Mountain region (Bohor and others, 1976). Field and mineralogical evidence indicate that the kaolinitic partings in these coals are actually altered volcanic ash layers. Knowledge of this mode of origin enhances the potential usefulness of tonsteins in correlation.

This report documents the occurrence of tonstein layers in some coals of the Raton coal field, the New Mexico portion of the Raton Basin (Fig. 1), and presents evidence for their volcanic origin. It does not discuss all the tonstein layers extant in the coal field, nor does it attempt to make any correlations using them. Because coal deposits are lenticular in the Raton

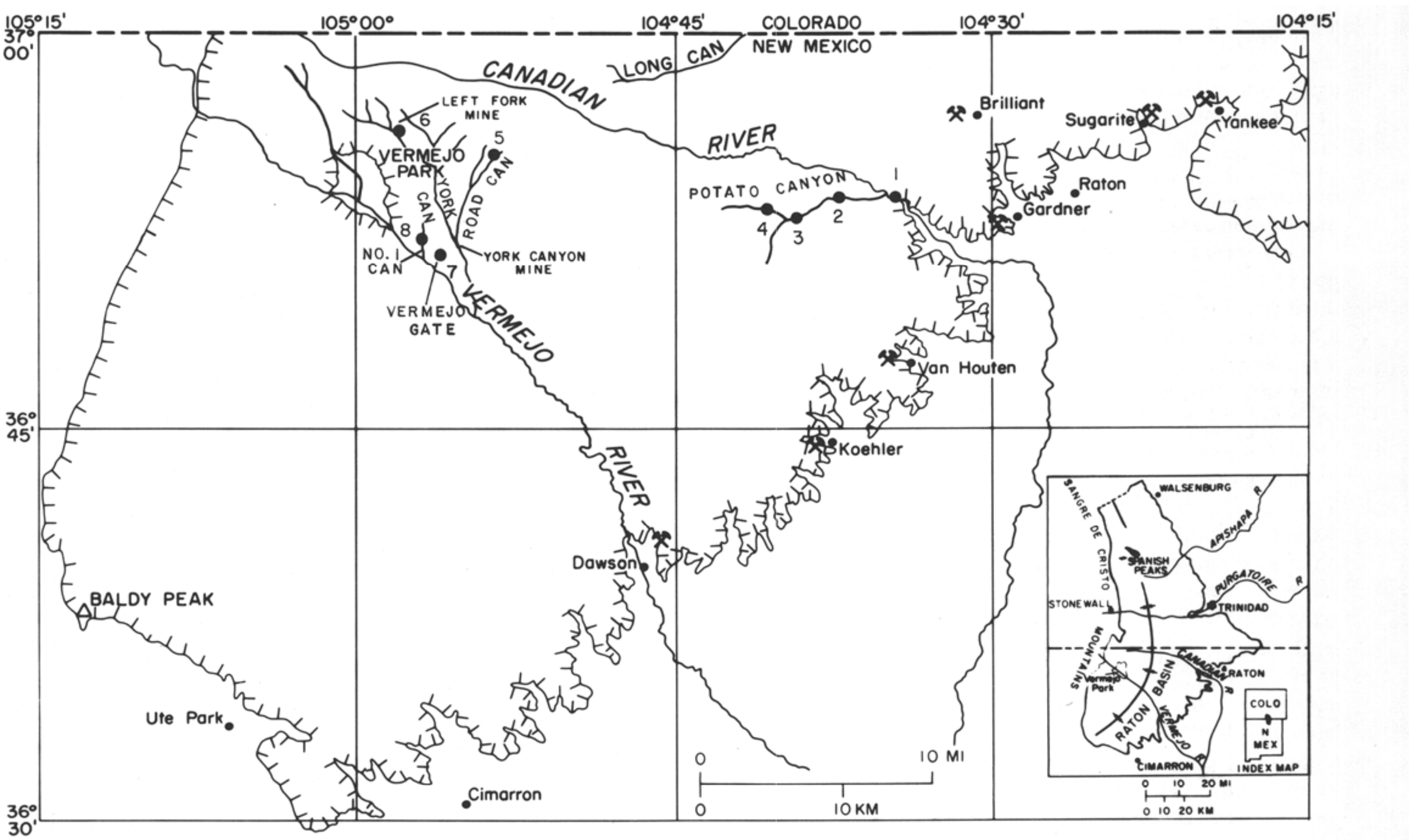

Figure 1. Raton coal field, Colfax County, New Mexico. Hachured line is approximate boundary; crossed picks show location of abandoned coal-mining camps. Numbered dots show location of coal beds in which tonsteins were sampled: 1, Raton bed, Canadian River; 2, Tin Pan bed, Potato Canyon; 3, Potato Canyon bed, Potato Canyon; 4, unnamed bed, Potato Canyon; 5, Chimney Divide bed, Road Canyon; 6, lower Left Fork bed, Left Fork of York Canyon; 7, "D" bed, at Vermejo Park gate; and 8, upper Left Fork (?) bed, No. 1 canyon. Index map modified from Johnson and Wood (1956).

coal field, the stratigraphy and correlations of individual coal beds present complex problems. We hope that this discussion of tonsteins will indicate their usefulness to geologists as a new tool for correlating coal beds in this area.

VOLCANIC ORIGIN OF TONSTEINS

Much of the potential usefulness of tonsteins in correlation results from their mode of origin. If they were composed of detrital clay distributed by feeder streams in the swamps during times of flood, they would have a restricted distribution and could be used only very locally for correlation; however, if they represent layers of widely distributed airborne volcanic ash that fell into the swamps during distinct episodes of eruption, as is here proposed, their usefulness in correlation over large areas becomes apparent.

Coal-forming swamps present ideal environments for the preservation of very thin ash layers, usually on the order of a few tenths of inches thick. Because of the absence of any reworking in coal-forming swamps, some of the thinnest ash beds can be traced over hundreds of square miles in coal beds that are continuous over wide areas. The fact that the tonstein layers commonly are so widespread and continuous at constant thicknesses almost eliminates the possibility of detrital origin.

Tonsteins are sometimes not found where they would be expected to occur. For instance, no visible tonstein layers can be seen in some very thick coals of the Rocky Mountain Region, such as the Wyodak bed near Gillette, Wyoming, and the Monarch bed near Sheridan, Wyoming (both Paleocene in age). An extremely rapid rate of accumulation of organic matter at these and many other locations might have caused organic material to be mixed with the ash as it fell into the swamp, rendering the ash invisible as a distinct layer to the casual observer. Absence of tonstein partings in any coal bed may be due to lack of volcanic ash.

What happens to a tonstein layer where it laterally passes out of a lenticular coal bed? Some layers may be traced with difficulty into the non-coal facies. The chances for volcanic ash to be reworked and redistributed are multiplied outside of a protected environment such as a coal swamp. Also, the environment of deposition is less acidic outside of coal-forming swamps, and the volcanic ash may not alter to kaolinite. Without the sharp color contrast of the white kaolinite with the black coal beds, the tonstein is difficult to distinguish.

Mineralogically, all the tonsteins from the Rocky Mountain Region including those from the Raton field, are composed chiefly of kaolinite, with varying amounts of quartz and heavy minerals such as zircon. Figure 2 shows the x-ray diffraction pattern of a typical tonstein from the Raton coal field. All peaks on the pattern belong either to kaolinite or quartz; this is evidence of a volcanic origin, because monomineralic clay partings of detrital origin in coal are atypical and almost unknown.

In the environment of the coal-forming swamps (low pH, fresh water and reducing conditions), fine-grained glassy volcanic ash (which is highly unstable in most natural environments) alters readily to kaolinite. A coarse porous ash, into which water could permeate easily, would partially recrystallize into large vermicular stacks of kaolinite, which are typical of tonsteins (Fig. 3). Other tonsteins reflect their volcanic origin by relic glass shards (Fig. 4), completely altered to kaolinite.

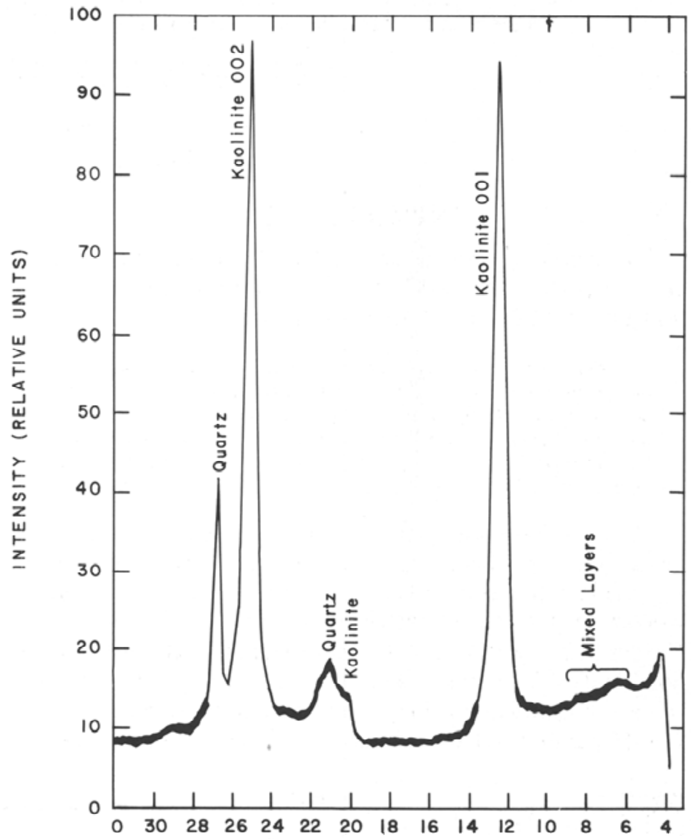

Figure 2. X-ray diffraction pattern of lower tonstein in the Tin Pan coal bed, Raton coal field, New Mexico. Major peaks of kaolinite and quartz are identified, as well as low, broad, diffuse peak of minor amount of mixed-layer clay.

Some of the tonsteins in the Raton coal field contain small amounts of mixed-layer clay besides kaolinite (Fig. 2). These tonsteins are found in the Lower Left Fork, the Tin Pan and the Chimney Divide coal beds. This non-kaolinite component of the clay-mineral fraction represents incomplete alteration of the volcanic ash to kaolinite, probably due to incomplete flushing of ions because of restricted water movement through swamps. The non-kaolinite component is small and the tonstein-parting mineralogy is still characterized by a preponderance of kaolinite.

The heavy-mineral suites of tonsteins, composed mainly of euhedral zircons, with minor amounts of other heavy minerals typical of volcanics, such as apatite (Fig. 5), also are suggestive of volcanic origin. Doubly-terminated prismatic zircons are characteristic of the heavy-mineral component of tonsteins, and these may provide fission-track ages (Bohor and others, 1976). No ages have been determined on tonsteins from the Raton field.

IDENTIFICATION OF TONSTEINS

Tonstein partings are recognized in the field by their white to light-gray weathering color, usually sharp contacts with the enclosing coal and blocky, massive appearance. They can readily be distinguished from ordinary silty or shalt' "bone" partings in coal simply by chewing a small fragment. Unless the tonstein is uncommonly rich in quartz or other non-clay minerals, it will be smooth and even-textured--not gritty or

Figure 3. Curved stacks of kaolinite vermicules typical of some tonsteins. Black bar at side equals 4 microns.

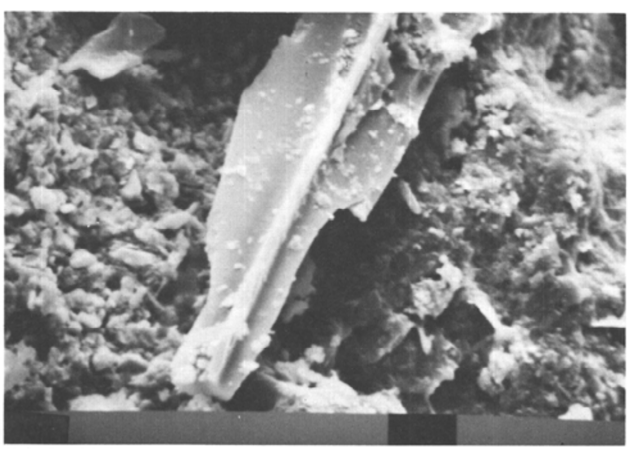

Figure 4. T-shaped (in cross section) relic glass shard in tonstein, now completely altered to kaolinite. Black bar at bottom equals 10 microns.

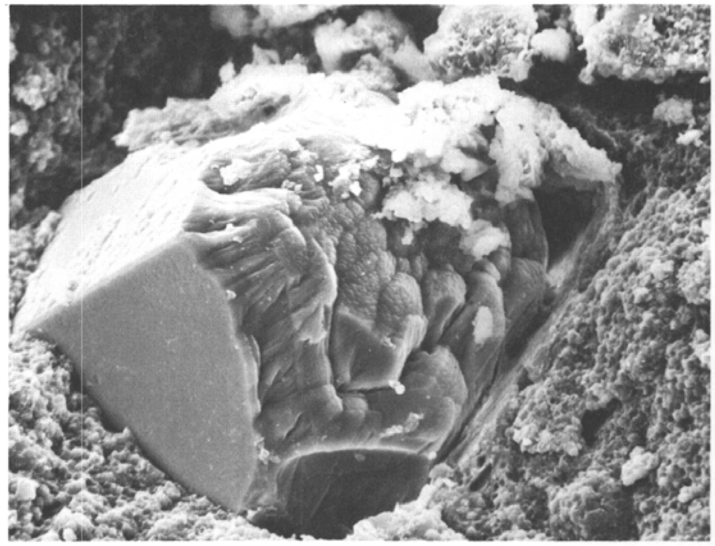

Figure 5. Euhedral apatite in tonstein from unnamed coal bed, Raton coal field, New Mexico. Fine-grained groundmass is kaolinite. Distance between white markers at bottom of photo is 30 microns.

silty. This characteristic of smoothness when chewed, as well as the irregular fracture and "resinous" luster, first directed attention to tonsteins in the Raton field in 1970.

All the partings that were sampled as tonsteins in the Raton coal field on the basis of field evidence were verified in the laboratory by x-ray diffraction for kaolinite content and examined by scanning electron microscope (SEM). All partings showed at least 90-95 percent of their clay component to be kaolinite. SEM examination showed a lack of shalt' texture in all samples, and the vermicular stacks of kaolinite characteristic of many tonsteins were common. Euhedral zircon, anatase (or rutile) and apatite crystals were identified with an energy-dispersive system.

GEOLOGIC SETTING

Tonsteins are restricted to coal-bearing facies and thus occur only in Upper Cretaceous and Paleocene strata in the Raton Basin (Fig. 1). Tonsteins of the Raton coal field all occur within coal beds of the Vermejo and Raton Formations (Fig. 6).

Tonsteins in coals of the Vermejo Formation

Several coal beds of varying thickness occur within the Vermejo Formation, but only the Raton coal bed, near the base of the formation and the Vermejo bed, near the top, can be identified and traced in the field. The Vermejo bed is limited to the western part of the field and was not examined for tonsteins.

Raton coal bed: This name is commonly applied to commercial coal beds at or near the base of the Vermejo Formation, regardless of whether the beds can be traced back to the Raton area.

Deposits of coal in the Raton bed are thick and pod-shaped (Fig. 7). Organic material that formed the coal was deposited in large swamps that were locally elongated parallel to a north- to northeast-trending beach (now represented by the Trinidad Sandstone). The coals in these pods are progressively older to the west; therefore, isochronous horizons cannot be traced between pods of Raton coal normal to depositional strike

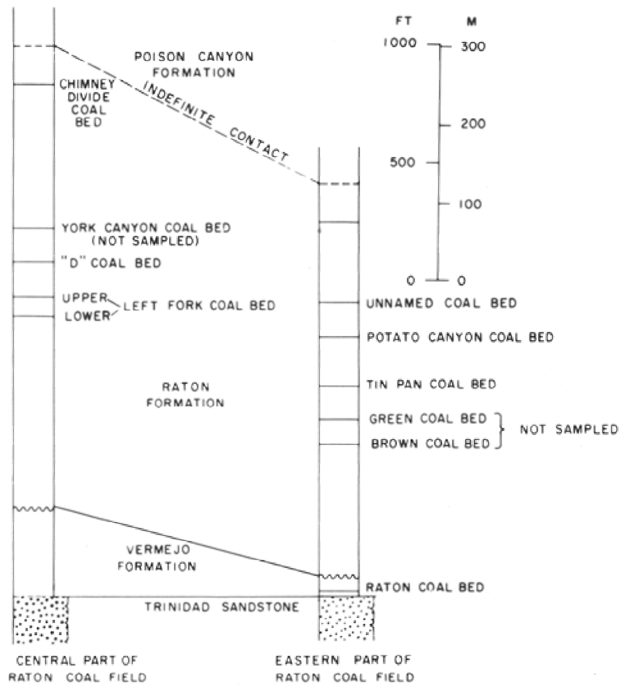

Figure 6. Generalized stratigraphic section of formations in the Raton coal field, Colfax County, New Mexico, showing relative positions of coal beds described in this report. (Positions of the Potato Canyon, Tin Pan, Green and Brown coal beds courtesy of Kaiser Steel Corporation.)

(NW-SE), but tonsteins will maintain their stratigraphic position in the coal pods when traced parallel to depositional strike (NE-SW).

Tonsteins in the Raton coal bed are exposed a few miles west of Raton on N.M. 555, at mileage 9.5 (Second Day Road Log). On the north side of the canyon, just across the bed of the Canadian River, is a good exposure of coals and carbonaceous beds in the lower part of the Vermejo Formation (Fig. 8). Because of their position with respect to the top of the Trinidad Sandstone, which is exposed in the riverbed, the lower five coal beds in this exposure are considered equivalent to the Raton coal bed. Only the second coal bed above the top of the sandstone contains tonstein layers. This 2 ft (0.6 m) bed contains three tonstein layers: 0.4, 1.4 and 1.6 ft (0.12, 0.43 and 0.48 m) above the base of the coal (Fig. 9).

Tonsteins in coals of the Raton Formation

Coal beds are also common in the Raton Formation (Fig. 6), but they are more lenticular and not as widely distributed as the coal beds in the Vermejo Formation. The coal beds containing tonsteins include the Tin Pan, the Potato Canyon, an unnamed bed, the Chimney Divide, the Lower Left Fork, the "D" bed and the No. 1 canyon bed. These coal beds are discussed in the order in which they appear in the Second Day Road Log (this Guidebook) rather than in stratigraphic sequence.

Tin Pan coal bed: The Tin Pan coal bed underlies an area of roughly 40 miles^2 (100 km^2) and about 4 miles (6.4 km) west of Raton; it lies stratigraphically about 800 to 850 ft (245 to 260 m) above the Trinidad Sandstone. The Tin Pan coal bed ranges in thickness from a thin streak to about 8 ft (2.4 m) and generally contains one or more shale partings as thick as 4 ft (1.2 m). It crops out along the Canadian River and in adjacent canyons. At 13.2 miles on the road log, in Potato Canyon, the Tin Pan coal bed is exposed in a bulldozer cut on the north side of the road near the junction with an old abandoned logging road. The coal section was measured as follows:

	Thickness	
	Feet	*Meters*
11. Mudstone	0.5	0.15
10. Coal	1.0	.3
9. Shale	.75	.23
8. Coal	1.6	.48
7. Shale	.1	.03
6. Coal	1.25	.38
5. Tonstein (sampled)	.15	.045
4. Coal (lower 3 in. impure and shaly)	1.00	.30
3. Tonstein zone, carbonaceous (sampled)	.1	.03
2. Coal	1.5	.46
1. Carbonaceous shale	6.0+	1.8+

The coal zone is 7.5 ft (2.3 m) thick here and contains 74 in. (187 cm) of coal. A 2 in. (5 cm) thick, hard, blocky tonstein parting, which weathers buff, occurs in the middle of the coal (Unit 5; see Fig. 10); and an irregular, reddish-brown carbonaceous tonstein about 1.5 in. (4 cm) thick occurs 1.0 ft (0.3 m) below it (Unit no. 3).

Potato Canyon coal bed: This coal bed lies roughly 100 ft (30 m) above the Tin Pan coal bed and about 950 ft (290 m) above the top of the Trinidad Sandstone. It occupies an area in part coincident with that of the Tin Pan coal but appears to extend farther to the south. Like the Tin Pan, the Potato Canyon bed ranges in thickness from 0 to about 8 ft (2.4 m) but is characterized by numerous shale partings.

A 1.5 in. (3.8 cm) tonstein parting was found in the Potato Canyon bed where it is exposed in a bulldozer scrape on the north side of the road at mileage 14.3 (Second Day Road Log). The tonstein is 4.5 ft (1.37 m) above the base of the coal; it is atypical because it has a very dark, even, fresh color (weathers buff) and a microcrystalline texture; however, it exhibits the blocky fracturing typical of tonstein partings. The Potato Canyon bed is exposed in a streamcut on the south side of Potato Canyon. A prospect entry has been driven into the coal bed at this location and the following section was measured at the mouth of the entry:

	Thickness	
	Feet	*Meters*
10. Sandstone, ledge-forming; shows channel Very fine-grained to fine-grained, light- to yellowish-gray.	10+	3+
9. Shale	1.0	0.3
8. Sandstone, lenticular, carbonaceous, brown-weathering	1.0	.3
7. Shale	1.25	.38
6. Coal	2.0	.61
5. Shale (or possible tonstein)	.1	.03
4. Coal	1.5	.04
3. Coal	.15	.04
2. Coal	2.65	.80
1. Carbonaceous shale	.5+	.15+

Unnamed Coal Bed: An unnamed coal bed is exposed high on the roadcut north of the road, at 16.5 miles (Second Day

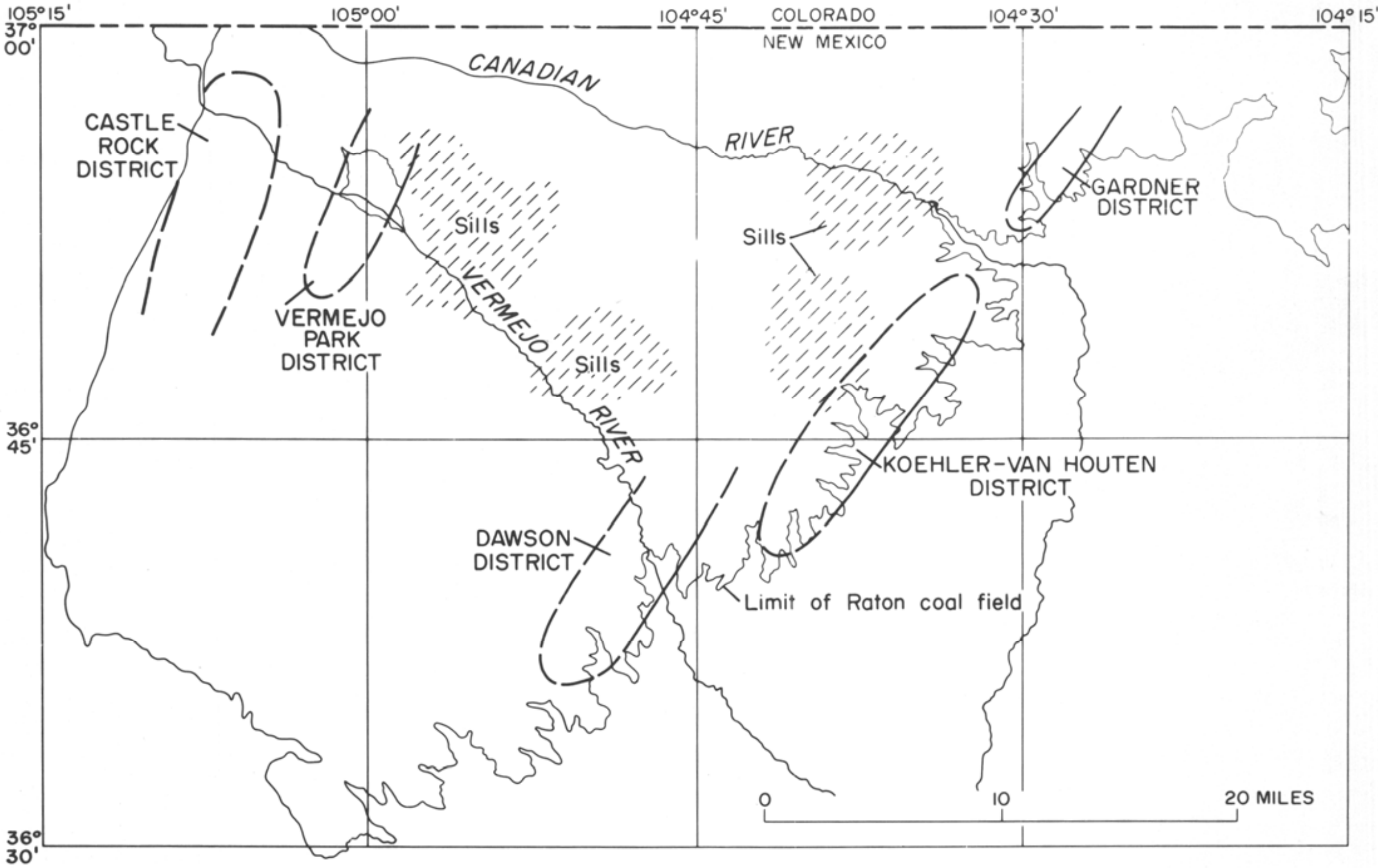

Figure 7. Location, approximate outline and orientation of thick, pod-shaped deposits of coal in the Raton coal bed, Colfax County, New Mexico (Pillmore, 1969).

Road Log); it contains three tonstein layers (Fig. 11). The middle tonstein is fairly coarse-grained and contains vermicular stacks of kaolinite crystals that are visible using a hand lens; the upper and lower tonsteins are finer grained.

Chimney Divide coal bed: This bed crops out below the crests of long fingerlike ridges and underlies high drainage divides throughout an area of more than 50 miles^2 (130 km^2) across the north-central portion of the Raton coal field. The coal bed commonly consists of two benches, each about 2 ft (0.6 m) thick, separated by a carbonaceous shale parting about 6 in. to 1 ft (0.15 to 0.3 m) thick. The Chimney Divide bed includes a series of coal lenses that lie at about the same stratigraphic position. It is near the top of the coal-bearing zone of the Raton Formation and generally is the highest coal

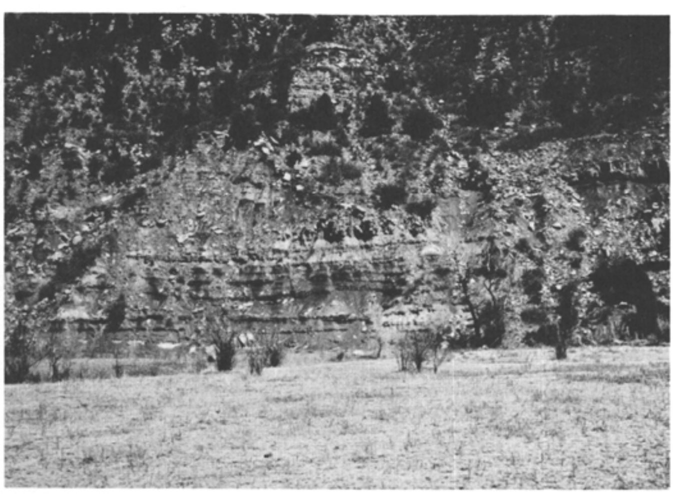

Figure 8. Stream cut bank exposure of lower part of Vermejo Formation, mileage 9.5 (Second Day Road Log), Canadian River canyon, New Mexico. Coal beds near base of cut constitute Raton coal bed.

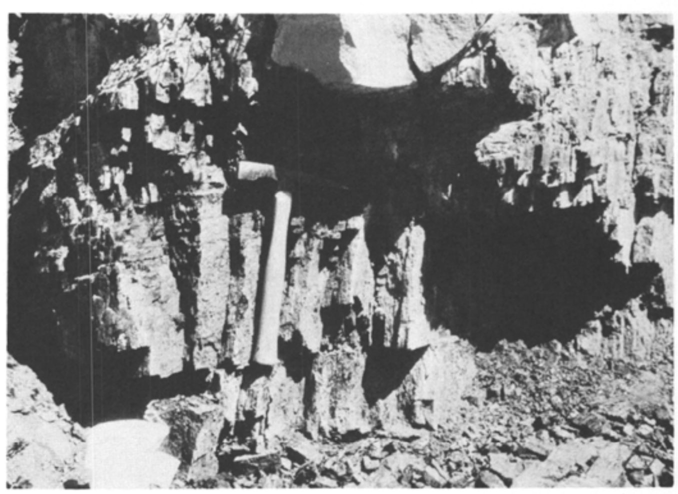

Figure 9. Close-up photograph of second coal bed from the bottom of Raton coal bed, mileage 9.5 (Second Day Road Log). Base of hammer shaft is on lowest tonstein (white layer); head is between middle and upper tonstein partings.

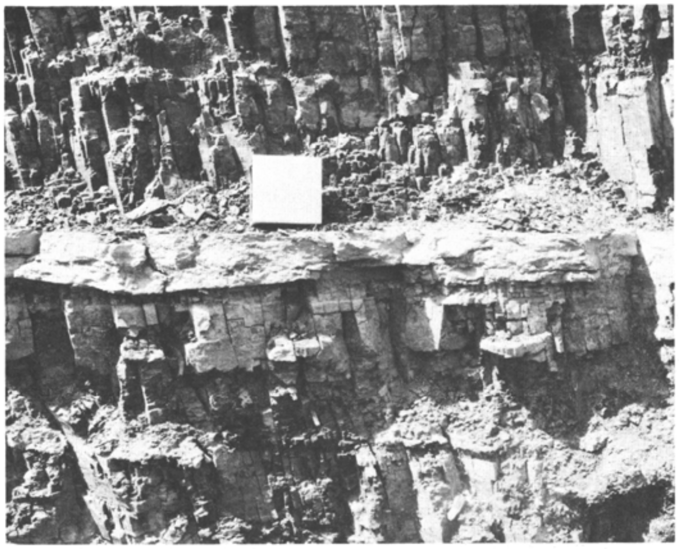

Figure 10. Thick upper tonstein in the Tin Pan coal bed at mileage point 13.2 (Second Day Road Log). Tape measure at top of the light tonstein layer is 2 in.[2]

bed in the sequence. It is about 1,800 ft (550 m) above the base of the Raton Formation and about 2,200 ft (670 m) above the Trinidad Sandstone in the vicinity of York Canyon, where the Raton Formation is thickest.

At 32.4 miles (Second Day Road Log), the Chimney Divide coal bed is exposed in the roadcut on the west side of the road. A 0.1 ft (3 cm) thick tonstein occurs in the upper part of the coal. The following section of the coal at this exposure shows the location of the tonstein layer:

	Thickness Feet	Thickness Meters
7. Mudstone, carbonaceous at base	1.0	0.3
6. Coal	.9	.27
5. Tonstein (sampled)	.1	.03
4. Coal	1.3	.39
3. Carbonaceous shale	.3	.09
2. Coal	1.7	.52
1. Mudstone	1.0+	.3+

If the Chimney Divide bed is a series of lenses of slightly different ages, this tonstein layer may not be everywhere present at this horizon.

Lower Left Fork coal bed: The Lower Left Fork coal bed is one of a pair of coal beds about 75 to 80 ft (23-24 m) apart near the base of the coal-bearing zone in the Raton Formation. The lower bed is about 1,200 to 1,250 ft (365-380 m) above the top of the Trinidad Sandstone and 950 ft (290 m) above the base of the Raton Formation in the vicinity of the Left Fork of York Canyon. Both beds attain a thickness of about 10 ft (3 m) in the northern part of the bed area, but split and thin to the south. The Lower Left Fork bed contains a tonstein parting at a stream-cutbank outcrop about 6 miles (10 km) up Left Fork Canyon from the York Canyon coal mine. This outcrop is off the main route and will not be visited on the field trip. The following section of the Lower Left Fork Coal was measured near the sampled locality (Fig. 12):

	Thickness Feet	Thickness Meters
7. Mudstone, weathers grayish-orange to brown	5.0	1.5
6. Carbonaceous shale	.15	.05
5. Coal—hard, vitric, conchoidal fracture	1.6	.49
4. Tonstein parting—hard, dark (weathers gray), conchoidal fracture (sampled)	.1	.03
3. Coal—hard, vitric, conchoidal fracture	1.9	.58
2. Carbonaceous shale	.6	.18
1. Carbonaceous mudstone and siltstone, weathers grayish-orange to yellow-brown.	1.0+	.3+

The tonstein in the Lower Left Fork bed is atypical in that it is very dark and hard, weathers gray instead of white, and has a conchoidal fracture.

"D" coal bed: At 38.8 miles (Second Day Road Log), the "D" coal bed (Pillmore, 1964) is exposed in the roadcut near the locked gate to Vermejo Park Ranch. The section exposed here is as follows:

	Thickness Feet	Thickness Meters
9. Claystone, carbonaceous at base, becoming silty upwards	5+	1.5+
8. Coal, top 2 in. (5 cm) stained yellow-brown	.66	.2

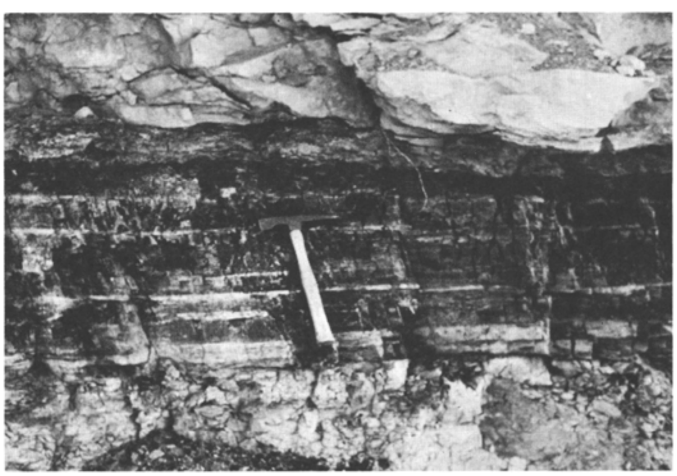

Figure 11. Three thin white tonstein layers in unnamed coal bed, mileage point 16.5 (Second Day Road Log). Hammer head is on middle tonstein; lower tonstein is prominent white layer halfway down hammer shaft.

Figure 12. Outcrop of lower Left Fork Canyon coal bed in stream-cut bank. Pack is lying on tonstein layer, which is indistinguishable from coal because of high organic content.

	Thickness Feet	Meters
7. Tonstein zone (sampled)-two thin resinous-appearing tonstein partings separated by a thin (1 in. or 2.5 cm) coal zone	.145	.04
6. Coal, thin shaly bone layers at base and about midway	1.95	.59
5. Coal, dirty and shaly	.45	.14
4. Coal	.33	.1
3. Claystone, carbonaceous	1.1	.33
2. Shale, appears micaceous, may be tonstein	.1	.03
1. Sandstone, carbonaceous, shaly, hard, brownish-gray. Contains plant fossils	1.0+	.3+

This unnamed coal lies about halfway between the Left Fork coal bed and the York Canyon coal bed, approximately 1,400 ft (425 m) above the top of the Trinidad Sandstone. Review of sections measured by Pillmore along the Vermejo River in the early 1960's shows that the two thin partings in the upper part of the coal bed, now known to be tonsteins, were then described as "clayey sandstone" having a rough texture. The coal bed was correlated for several miles along the Vermejo River and in some of its tributaries on the basis of the tonstein partings.

No. 1 Canyon Coal Bed: At 39.8 miles (Second Day Road Log), No. 1 canyon, a tributary to the Vermejo River canyon, leads off to the northeast. Approximately 0.3 mile (0.5 km) up this canyon, a coal bed crops out that may correlate with one of the Left Fork beds, probably the upper. This bed contains a thin tonstein (Fig. 13), as shown on the section below:

	Thickness Feet	Meters
6. Carbonaceous shale, fissile, black	1.0	0.3
5. Coal, bottom 4 in. (10 cm) hard and bony	1.2	.37
4. Claystone and carbonaceous, coaly shale	2.75	.84
3. Coal, with bony layer 12 in. (30.5 cm) above base	1.63	.5
2. Tonstein parting (sampled)	.1	.03
1. Coal, 1 in. (2.54 cm) bony layer 10 in. (25.4 cm) above base	1.95	.6

Other Tonstein Occurrences

Tonsteins have been found in several coal beds of the Vermejo and Raton Formations in roadcuts along Interstate 25 on both sides of Raton Pass (Third Day Road Log), but the specific localities are not recorded here because the tonsteins are similar to those already described. A 3 in. (8 cm) tonstein was discovered in the Brookside coal bed (Vermejo Formation) of the Cation City field south of Florence, Colorado, in a northward extension of the Raton Basin in Colorado.

CONCLUSIONS

Although the occurrence of distinctive clay partings in coals of the Raton field has been known for many years, their recognition as tonsteins (altered volcanic ash) and their potential as isochronous marker beds have only recently been realized. Because of their volcanic origin, these tonsteins offer an additional means of correlating coal beds in the stratigraphically complex coal-bearing rocks of the Raton Basin, and their radioactive zircon content may provide radiometric ages on coals.

Figure 13. Outcrop of No. 1 canyon coal bed. Head of shovel is on tonstein layer.

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