THICKNESS CHANGE INVOLVED IN THE PEAT-TO-COAL TRANSFORMATION FOR A BITUMINOUS COAL OF CRETACEOUS AGE IN CENTRAL UTAH[1]

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ABSTRACT: The ratio of the thicknesses of a layer of peat and the coal bed formed from that peat has been calculated for a bituminous coal bed in central Utah. The method used involves comparison of the thickness of peat eroded by a laterally migrating channel system with the thickness of coal now absent from the outcrop. The peat:coal thickness ratio calculated by this method is approximately 11:1.

INTRODUCTION

The amount of compaction of sediments in their transformation into sedimentary rocks is an important factor in stratigraphic analysis (Weller, 1959; Conybeare, 1967). It is particularly important in the study of coal and coal-bearing strata inasmuch as the compaction and eventual coalification of peat involves a compaction factor or "shrinkage coefficient" (Zaritsky, 1975) that is several to many times as great as those for other sediments (Weller, 1959). Restored cross sections through coal-bearing strata often make better stratigraphic sense when coal bed thicknesses are expanded to approximate the thicknesses of the beds of peat that were their precursors (Beaumont and Shomaker, 1977; Ryer, Phillips, Bohor, and Pollastro, 1980). There is, however, no general agreement on what compaction factor to use in preparing reconstructions of this type. We describe a simple method of stratigraphic analysis that we have used to determine the peat:coal thickness ratio for a high volatile bituminous coal in central Utah.

PREVIOUS ESTIMATES

A variety of methods has been utilized to estimate compaction factors for the peat-to-coal transformation. A summary of previous estimates is presented in Table 1. The methods employed by the various authors to arrive at these values fall into four categories: 1) petrographic: the direct observation of the deformation of objects contained in coal whose original shapes are known, such as plant cells, spores and palynomorphs; 2) density: the comparison of the density of modern peat with that of coal, taking into account both early compaction and chemical alteration during coalification; 3) stratigraphic: the comparison of the thickness of original peat, as restored by stratigraphic reconstruction, with coal thickness; and 4) inclusions: the evaluation of the amount of deformation of formerly flat-lying surfaces around incompressible objects that were present in the original peat, such as concretions, or observation of thickness increase of a coal bed where such objects are present.

The peat:coal thickness ratios presented in Table 1 range from 1.4:1 to 30:1. The median ratio is 7:1. The great range of values is probably explainable in terms of a number of factors, including the following: 1) problems inherent in the various methods employed (e.g., at what stage of compaction do coal balls form in peat?); 2) variations in the values used for the density of peat (e.g., some authors distinguish between "uncompacted vegetable matter," "uncompacted peat," and "well-compacted peat," while others do not; 3) variations in the rank and, therefore, density of different coals; and 4) variations in the ash content of coals. A discussion of the contributions of these factors is beyond the scope of this paper. The interested reader is referred to papers by Ashley (1907), Weller (1959), Bloom (1964), and Zaritsky (1975) for more information.

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TABLE 1.—*Previous estimates of peat:coal ratio*

Author	Peat:Coal Thickness Ratio	Method	Comments
Renault, B., 1899	12:1 to 30:1	petrographic?	observations regarding "shrinkage of stems of trees in passing from wood to (bituminous) coal"; French literature cited by Moore
Ashley, G. H., 1907	3.5:1	density	for "well-compressed" peat to bituminous coal
	4:1 to 7:1	stratigraphic	reconstructed original peat thickness in small coal basin compared to present coal thickness; for bituminous? coal
	4:1 to 20:1	stratigraphic	thickness variations of coal bed relative to topography of surface underlying coal; for butuminous? coal
	1.4:1 to 2:1	stratigraphic	reduction of coal thickness beneath sandstone "rock rolls" (erosional channels); for bituminous? coal
Glockner, F., 1912	2.5:1	inclusions	"draping of coal over tree stump at base of seam; for brown coal; German literature cited by Stutzer (1940)
Thiessen, R., 1920	(5:1 to 40:1)	petrographic	not directly applicable to peat:coal ratio; observations on compression of plant cells recognizable in coal
Lewis, J. V., 1934	10:1	density	for bituminous coal
	13:1	density	for anthracite coal; values 50% greater for uncompacted vegetal matter:coal
Raistrick, A., and Marshall, C. E., 1939	15:1	—	for "uncompacted" peat; no specific data cited
Stutzer, O., 1940	2.2:1	inclusions	increase in thickness of coal bed where coal balls are present; for bituminous? coal
Mott, R. A., 1943	12.5:1	density	for anthracite coal
Kolotukhina, S. E., 1949	4:1 to 5:1	—	Russian literature cited by Zaritsky (1975)
Rukhin, L. B., 1953	20:1 to 30:1	—	Russian literature cited by Zaritsky (1975)
Kosanke, R. M., Simon, J. A., and Smith, W. H., 1958	3:1	inclusions	increase in thickness of coal bed where coal balls are present; for bituminous coal
Weller, J. M., 1959	20:1	density	calculation based on decrease of volatile matter in coals of increasing rank with fixed carbon considered as a constant; value cited here is for bituminous coal
Bobrovnik, D. P., 1960	30:1	—	Russian literature cited by Zaritsky (1975)
Prikhodko, Y. N., 1963	5.9:1	stratigraphic	Russian literature cited by Zaritsky (1975)
Bloom, A. L., 1964	5:1 to 10:1	stratigraphic	reconstructed original vs compacted thicknesses for sedge peats 1,000 to 7,000 yrs old
Volkov, V. N., 1964	2.5:1	—	for brown coal
	5:1	—	for bituminous? coal
	7:1	—	for anthracite coal; Russian literature cited by Zaritsky (1975)
Falini, F., 1965	10:1	density	for brown coal
	20:1	density	for bituminous coal
Williamson, I. A., 1967	7.5:1	—	a modification of the 15:1 value cited by Raistrick and Marshall (1939) taking into account the "compression" of peat with depth of burial
Stach and others, 1975	7:1 to 20:1	inclusions	for bituminous coal
Zaritsky, P. V., 1975	5:1	inclusions	compaction around carbonaceous coal balls (sulfide and siliceous concretions, formed later, give lower ratios)
Stanton, Ron, U.S.G.S., 1979 (written comm.)	3:5:1 to 4:1	inclusions	compaction around pyrite framboids contained in vitrinite; for bituminous coal
	(7:1)	petrographic	not directly applicable to peat:coal ratio; for compaction of woody tissue
	(20:1)	petrographic	not directly applicable to peat:coal ratio; for compaction of spores
Ryer, Phillips, Bohor, and Pollastro, in press	10.6:1	stratigraphic	reconstructed original peat thickness in basin compared to present coal thickness; a minimum value; for bituminous coal

AN ESTIMATE FROM CENTRAL UTAH

An Interstate 70 road cut through the Upper Cretaceous Ferron Sandstone Member of the Mancos Shale on the west flank of the San Rafael swell, central Utah, approximately 6 km east of the intersection of I-70 and Utah Highway 10, displays a sandstone split in the I coal bed of the Emery coal field (Fig. 1). A sketch depicting the interpreted depositional and post-depositional history of the units exposed in the cut is shown in Figure 2. This stratigraphic setting permits calculation of the peat:coal ratio for this particular coal bed by the following method: 1) the original bed of peat and the overlying bed of clay are assumed to have been of constant thickness over the length of the exposure, a distance of 90 meters; 2) at any given vertical section along the exposure, the thickness of the sandstone channel fill is assumed equal to the thickness of original clay or original clay plus peat eroded as the channel migrated towards the left in Figure 2c; and 3) for those sections in which the erosional base of the channel sandstone body is in contact with the coal, the thickness of coal now missing may be compared to the original thickness of peat eroded by the channel, thus establishing the peat:coal thickness ratio.

Twenty-eight closely spaced sections were measured through the units exposed in the road cut. Two of the sections were measured on natural exposures adjacent to the cut; 26 were measured in the road cut itself. The thicknesses of the lower coal bed and the overlying claystone unit were measured directly with a tape; those of the channel sandstone were measured with an alidade. The data so obtained are plotted in Figure 3. At the left on Figure 3 are data points for that part of the exposure where the base of the channel rests erosionally on the claystone unit overlying the coal. At the right are points for that part of the exposure where the channel rests on the coal. Lines have been fitted to the two sets of data by least squares linear regression. In both instances the data are well described by the lines (correlation coefficients, r, are −0.98 and −0.83, respectively). Put simply, as the thickness of the channel sandstone unit increases, first the claystone unit and then, after complete removal of the claystone, the coal decrease in thickness. These thickness changes are described by inverse linear relationships. The slopes of the two lines are −0.49 and −0.089, respectively, indicating that the channel sandstone unit increases by 2.1 meters for each meter of decrease in the thickness of the claystone and by 11.3 meters for each meter of coal. Assuming that there was no compaction involved in the transition from sand to sandstone, the following compaction ratios are established: clay:claystone = 2.1:1; peat:coal = 11.3:1.

DISCUSSION

A critical assumption in the preceeding analysis is that the original sand channel fill

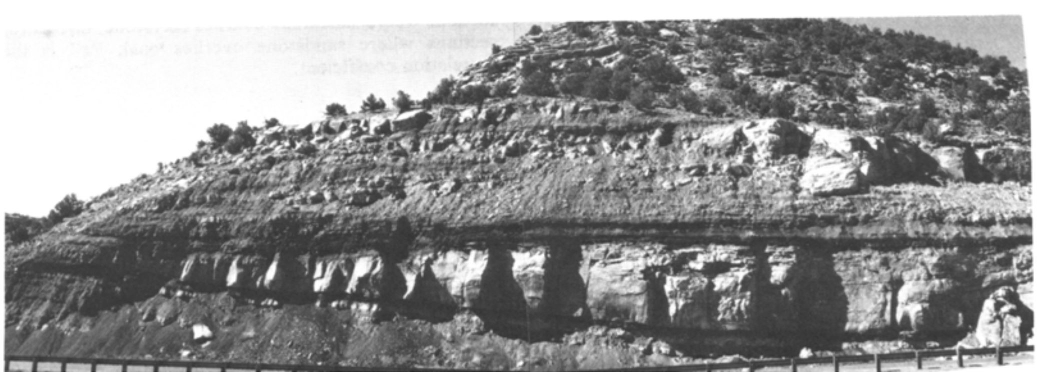

FIG. 1.—Sandstone split in I coal bed of Emery coal field, central Utah, exposed in road cut along Interstate 70. Note lateral accretion surfaces dipping towards the left in the sandstone unit.

has undergone no compaction in the transformation to sandstone. Four thin sections were made of samples from various parts of the channel to assess the validity of this assumption. Three samples from the part of the channel that overlies the coal show no evidence of compaction. The sandstone is clearly grain-supported with no evidence of interpenetration of grains. It is quite clean with most of the original porosity remaining. The sandstone that overlies the claystone unit, representing filling of the partially abandoned channel under lower energy conditions, contains a considerable amount of carbonaceous plant material ranging in size from finely-divided material to twigs and

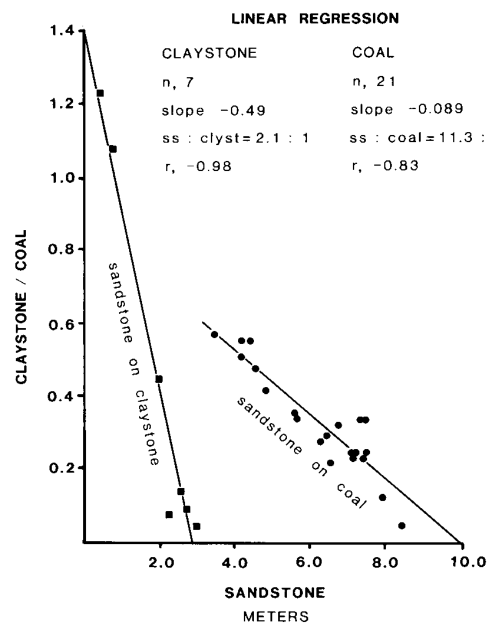

FIG. 3.—Thickness data from 28 sections measured through units exposed in road cut. Squares are for sections where sandstone overlies claystone; circles for sections where sandstone overlies coal; "r" is the correlation coefficient.

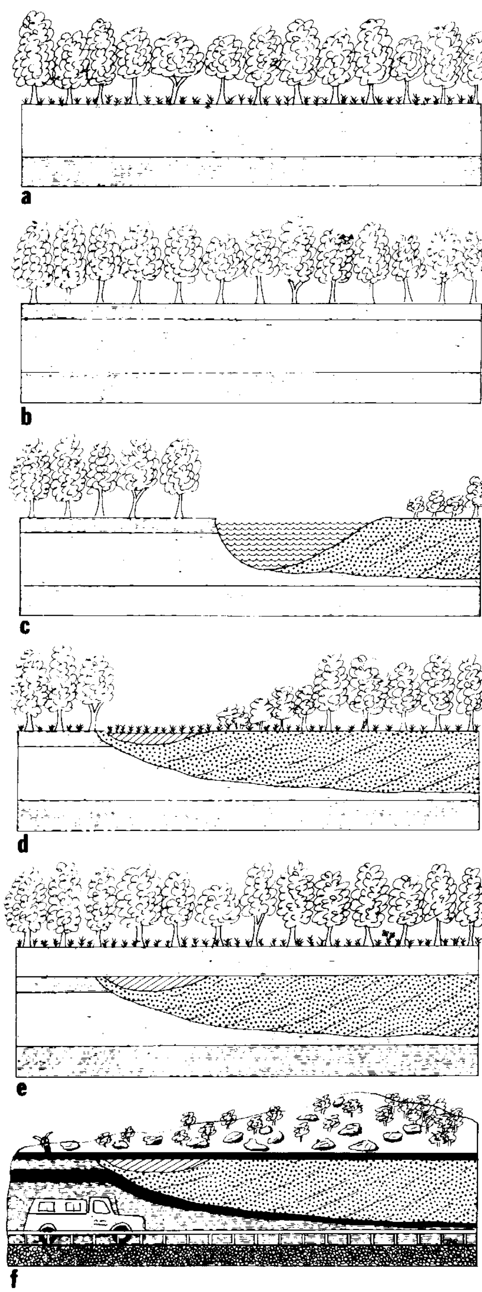

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FIG. 2.—Schematic diagram depicting interpreted history of units exposed in roadcut pictured in Figure 1 (lithologic symbols as in Fig. 4): a) layer of peat accumulates above layer of clay; b) layer of peat covered by layer of clay, probably overbank deposits from the channel system approaching from the right; c) laterally migrating channel erodes peat and clay on cut bank, deposits sand on point bar; d) channel is abandoned; e) peat accumulating environment is reestablished and layer of peat develops over older sediments; f) compaction, coalification, lithification and the efforts of the highway department produce the road cut exposure shown in Figure 1.

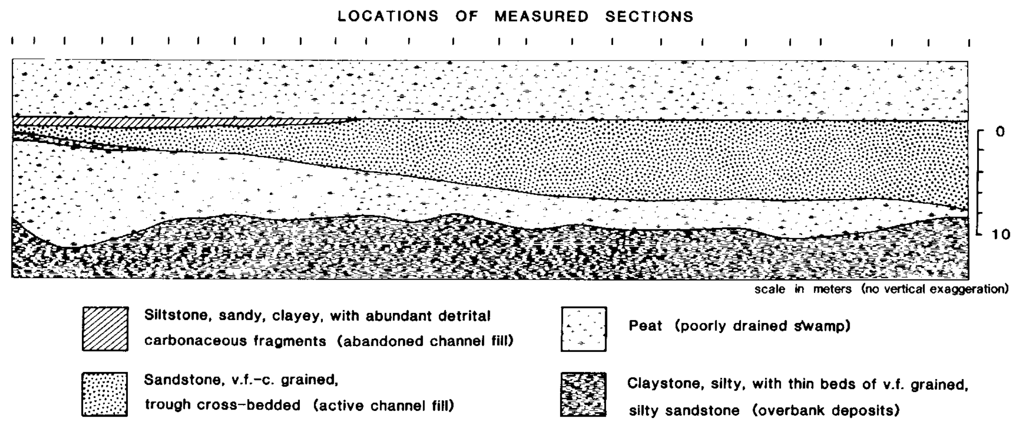

FIG. 4.—Restored cross section showing original configuration of units exposed in road cut. Coal has been expanded times 11.3 to approximate original thickness of peat; claystone expanded times 2.1 to approximate original thickness of clay. Datum is top of channel-fill unit.

small logs. Some amount of compaction has undoubtedly occurred in this sandstone though the amount probably does not exceed 10 to 15 percent. Still, the clay:claystone ratio must be viewed with some suspicion and the 2.1 compaction factor should probably be reduced by some small amount. As there is no evidence of compaction in the sandstone that directly overlies the coal, the peat:coal thickness ratio of 11.3:1 is considered accurate.

The compaction factor of 11.3 for the transformation of peat to bituminous coal is well within the range of values shown in Table 1 though it is considerably higher than the median value of 7. The 11.3 value is applicable to uncompacted to moderately well-compacted peat inasmuch as the original layer of peat plus overlying mud totalled only about 10 meters in thickness at the time it was eroded by the laterally migrating channel.

Our data, then, indicate that a peat:high volatile bituminous coal thickness ratio of approximately 11:1 is applicable for use in restoration of Cretaceous stratigraphic sections in cases where the original beds of peat are depicted as occupying a position at or near the depositional surface. The compaction factor of 11.3 has been used in the production of Figure 4, a restored section showing the original configurations of the units present on the outcrop pictured in Figure 1. For restorations showing Cretaceous peat beds of much greater thickness or peat beds buried beneath additional layers of sediment (i.e., in instances where compaction of the original peat would be greater), a smaller compaction factor must be used.

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