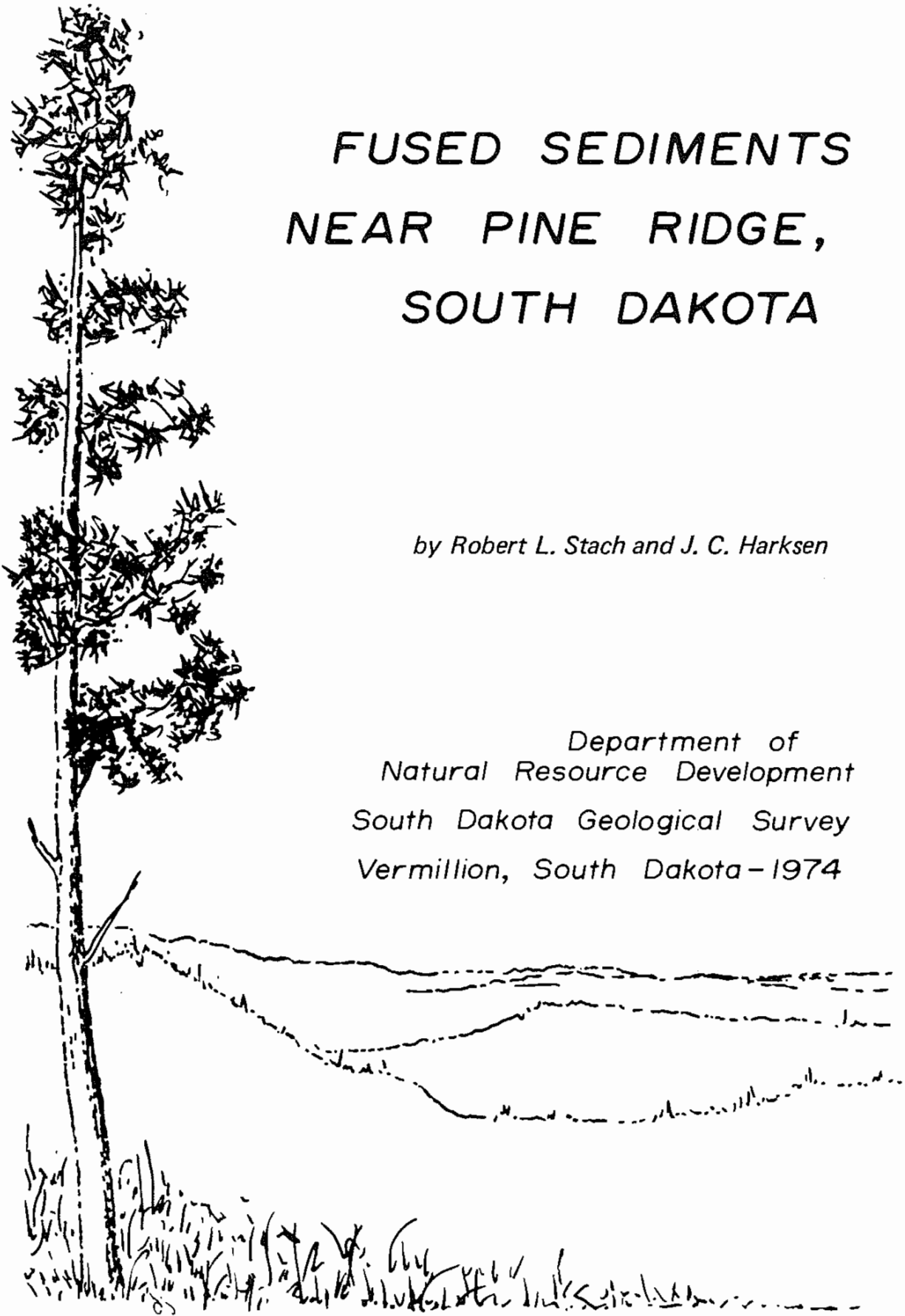


**FUSED SEDIMENTS
NEAR PINE RIDGE,
SOUTH DAKOTA**

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South Dakota Geological Survey
Vermillion, South Dakota-1974



FUSED SEDIMENTS NEAR PINE RIDGE, SOUTH DAKOTA ¹

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ABSTRACT

In southwestern Shannon County, South Dakota, there are 13 separate occurrences of fused, red, brick-like material. These deposits bear a striking resemblance to the clinker beds formed by burning coal seams. Eight deposits are scattered throughout the upper 100 feet of the Niobrara Chalk and an additional five deposits are located in the lower 70 feet of the overlying Pierre Shale.

Samples of the fused sediment were analyzed using a General Electric XRD-6 x-ray diffractometer. In order of estimated abundance, the deposits were composed of quartz, tridymite and/or cristobalite, hematite, and indialite, which is a polymorph of cordierite. This marks the first recorded natural occurrence of the mineral indialite in South Dakota.

The mineral assemblage proves the sediment was heated to a very high temperature and that the heating was of short duration. It is suggested that the heat resulted from either ignition of the organic rich sediments of the basal Pierre Shale and upper Niobrara Chalk or the venting of natural gas from the Niobrara Chalk.

INTRODUCTION

West of Pine Ridge, South Dakota, along the flanks of the Chadron Arch (Fig. 1) are many deposits of fused, red, brick-like material. These deposits bear a striking resemblance to the clinker beds formed by burning coal seams. The presence of the beds as well as their resemblance to clinker beds was noted by Dunham (1961) who attributed their origin to the burning of oil contained in the original sedimentary rocks.

OCCURRENCE

The fused sediments have been mapped in 13 separate deposits flanking the Chadron Arch in southwestern Shannon County, South Dakota (Harksen, in preparation). Eight deposits are scattered throughout the upper 100 feet of the Niobrara with an additional five deposits located in the lower 70 feet of the Pierre

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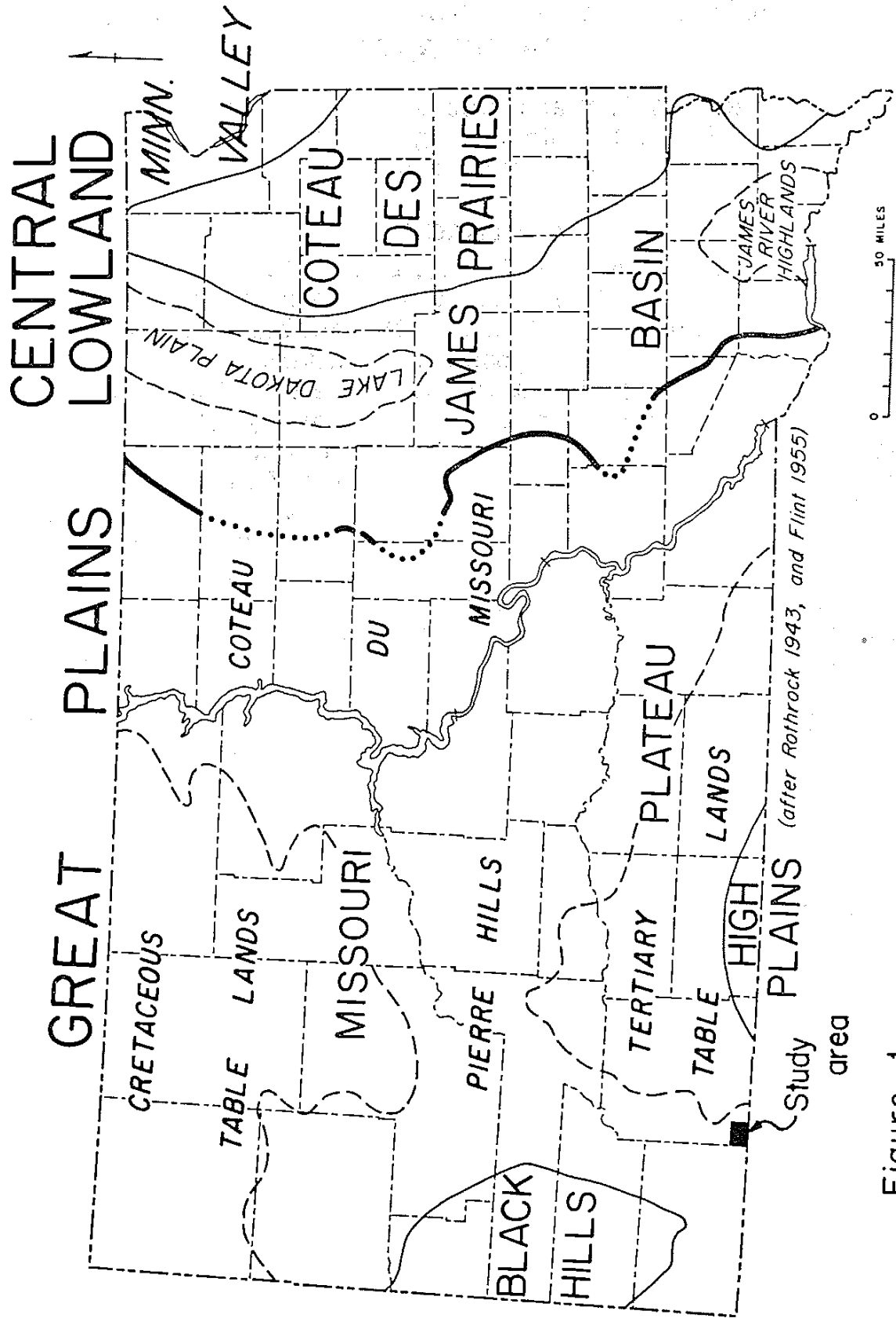


Figure 1.

Shale. Stratigraphic correlation of the deposits has proved to be impossible due to: (1) a lack of marker beds (especially in the Niobrara Chalk); (2) the large number of minor faults and folds negates any attempt to correlate the beds on the basis of elevation alone; (3) the resistance of the beds to erosion generally predicates their occurrence as isolated topographic highs (much like tepee buttes).

The surface of the deposits is usually littered with a reddish-brown, brick-like material. In situ, the deposits appear to occur vertically along joints and are highly variable in size with vertical and horizontal dimensions on the order of 20 feet or more. The material laterally grades from a metallic, black scoriaceous center to a hard, dense, brick-red material at the edge.

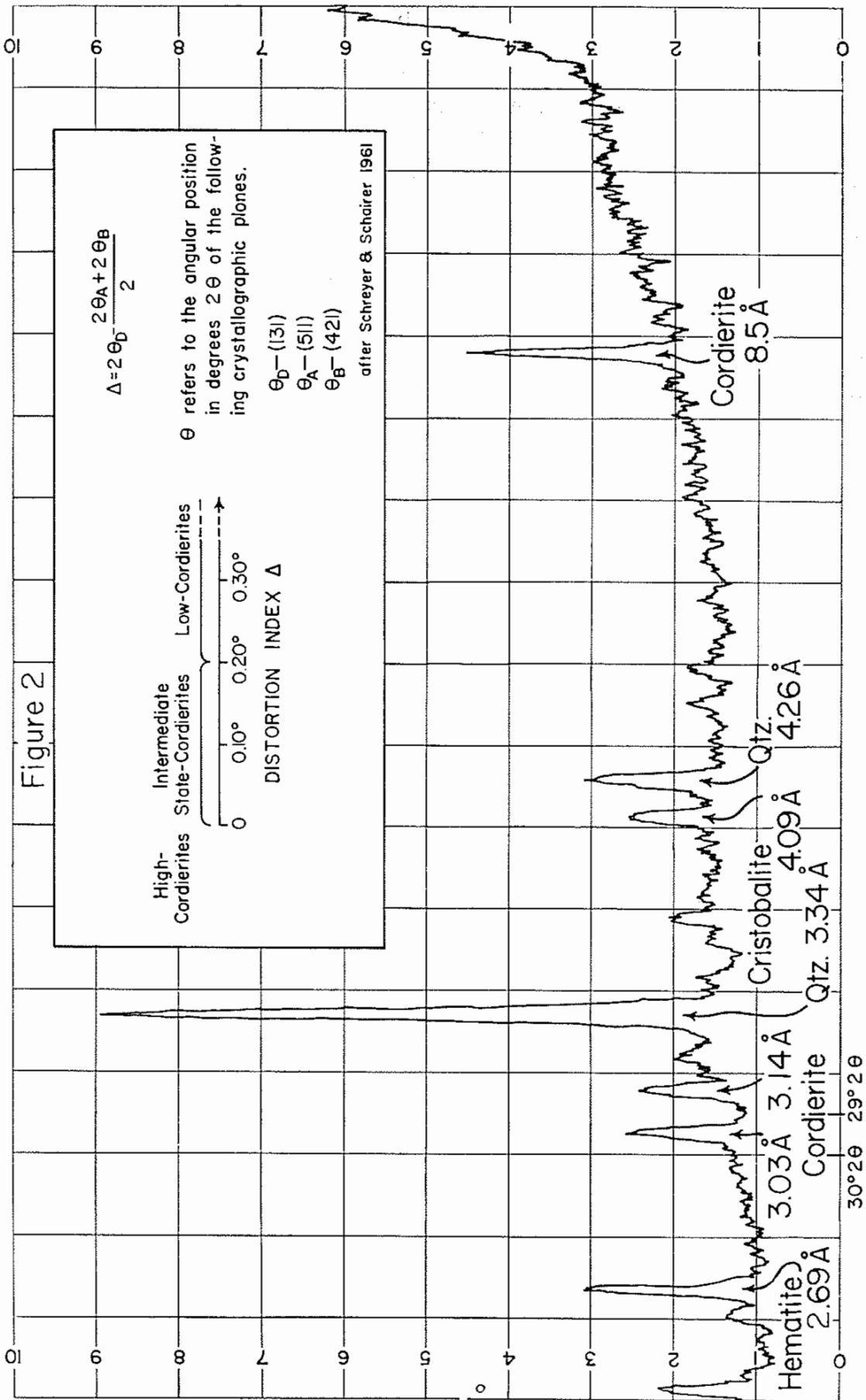
LABORATORY ANALYSIS

In hand specimen the material resembles common brick, being fine-grained, hard, dense and brick-red. Except for secondary gypsum crystals along fractures, the material was so fine-grained that all mineral identification was done through use of a General Electric XRD-6 x-ray diffractometer. Operating parameters of the diffractometer were as follows: the trace was recorded on a linear scale using nickel filtered, copper $K\alpha$ radiation generated at 35KV and 35MA; routine scanning speed was $2^\circ 2^\circ/\text{min}$. with detailed scans at $0.1^\circ 2^\circ/\text{min}$.

Minerals detected (in order of their estimated abundance) were quartz (SiO_2), tridymite and/or cristobalite (high temperature polymorphs of quartz), hematite (Fe_2O_3) and indialite, a polymorph of cordierite. Microscopic examination showed that the samples also contained numerous calcined fish bones and scales which are present as a soft white powder with casts of the bones and scales preserved in very fine detail. Growth lines of the fish scales can still be seen in many instances.

Indialite, a hexagonal polymorph of cordierite ($\text{Mg}_2\text{Al}_4\text{Si}_5\text{O}_{18}$), was originally described from the fused sediments of the Bokaro coalfield, India (Miyashiro, et al., 1955). Since that time indialite or a material structurally intermediate between indialite and common orthorhombic cordierite has been described from blast-furnace linings, xenoliths, pegmatites and a wide range of metamorphic and pyrometamorphic rocks. In view of the continuous nature of the structural series Schreyer and Schairer (1961) have proposed that the series be divided into high and low cordierite based on a distortion index Δ (Fig. 2), with high cordierite ($\Delta = 0$) being synonymous with indialite.

Schreyer and Schairer (1961) state in the system $\text{MgO-Al}_2\text{O}_3-$



SiO₂ high cordierite is the first cordierite to form at all temperatures and compositions. With continued heating this metastable high cordierite is found to transform through intermediate cordierite to low cordierite. Natural high cordierite found in rocks formed at high temperatures is believed to be a metastable phase preserved because the duration of heating was insufficient to produce the stable low cordierite. Schreyer and Schairer working with the para-lavas of the Bokaro coalfield in India, similar in bulk chemical composition to the sediments under discussion, found cordierite starts to crystallize at $1,295 \pm 5^\circ\text{C}$.

While the cordierite in the samples from Shannon County would appear to fit the definition of high cordierite (only one diffraction peak between $29-30^\circ 2\theta$) the width of the peak (Fig. 2) suggests there is more than one structural state present.

The cordierite, tridymite and cristobalite all point to the high temperature to which the sediment has been subjected. Quartz with the high temperature polymorphs, tridymite and cristobalite, is a non-equilibrium assemblage and suggests high temperatures of short duration. The presence of high cordierite leads to a similar conclusion; thus all evidence points to a sediment that was heated to a very high temperature for a short period of time.

There are two possible sources for the tremendous amounts of heat needed to produce the mineral phases present in the samples. The first would be ignition of the oil present in the lower Pierre Shale. It has long been known that the Sharon Springs member of the Pierre Shale would burn and several small outcrops of burned shale have been reported from near the Missouri River in Gregory County (Rothrock, 1944, p. 137) and Lyman County (Gries and Rothrock, 1941) South Dakota. Laboratory tests have confirmed earlier reports that large amounts of heat must be supplied to first distill and then ignite the oil. Dunham (1961) reports two analyses of shale from southwestern Shannon County. One sample contained 2.8 gallons of oil per ton and the other contained 1.0 gallon of oil per ton. Thus, in order to create the fused sediments, a large mass of sediment would be required, and after initial ignition, the heat would have to be confined in order to retort enough oil from the surrounding sediments to maintain the reaction.

An alternate source of heat would be the ignition of natural gas from the Niobrara Chalk. Natural gas has been produced from the Niobrara in several parts of the State and several gas shows have been reported from the Pierre-Niobrara contact (Rothrock, 1944).

At the present time sufficient evidence is lacking to prove or disprove either of the above hypotheses. Whichever mechanism

prevailed, field evidence seems to indicate that the heat was confined in vertical joints with the highest temperatures along the walls of the joint. Lack of collapse features and the preservation of the fine detail of the contained fossils would indicate that the combustion reaction was not particularly violent.

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