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INFLUENCES ON THE POSITION OF CHESTERIAN SAND BELTS IN INDIANA

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ABSTRACT: The axial trend of belt sand bodies in the Hardinsburg Formation in Indiana shows striking similarities to the axial trends of belt sand bodies in earlier Chesterian formations of the West Baden Group and in the overlying Tar Springs and Waltersburg Formations. Droste and Horowitz (1990) postulated that the belt sand bodies of the Hardinsburg Formation in Indiana resulted from focussed current action on quartz sands funnelled along sea floor lows. The sea floor lows marked locations where local increased rates of subsidence were produced by subtle adjustments in basement structures. We infer that all the belt sands in the Indiana Chesterian resulted from deposition controlled by the same factors and that their trends mark locations of changing loci of minor basement structural adjustments These trends are generally parallel to the tectonic movements that produced the structures associated with the LaSalle Anticlinal Belt and Wabash Valley Fault System.

INTRODUCTION

In this review, our principal purpose is to illustrate that the axial trend of belt sand bodies in the Hardinsburg Formation in Indiana shows striking similarities to the axial trends of several other belt sand bodies in other Chesterian formations in Indiana. Potter (1962, 1963) has published a classification of elongate sand bodies, and we use herein his characterization of belt sand bodies.

CHESTERIAN BELT SANDSTONES

Major belt sand bodies in the subsurface of Indiana occur in the West Baden Group, the Stephensport Group, and in the lower part of the Buffalo Wallow Group (Figure 1). Because erosion in Indiana associated with the formation of the Mississippian unconformity has greatly reduced the geographic occurrence of Buffalo Wallow rocks above the Menard Limestone (Figure 1), the distribution of sandstones in the formations of the middle and upper parts of the Buffalo Wallow Group are not included in this study. Table 1 compares the major belt sand bodies in the Chesterian of Indiana.

West Baden Group

The belt sands in the West Baden Group (Figure 2) lie in the rocks called the West Baden Clastic Belt by Sullivan (1972). In many locales in the West Baden Clastic Belt, all or almost all of the West Baden interval is belt sandstone. The West Baden belt sands extend northeastward from Vanderburgh County to Pike County, where they continue in two diverging orientations (Figure 2). One trend extends northwestward from Pike County into Sullivan County. The other trend extends from Pike County northeastward into Owen County (Figure 2). The net sandstone thickness is greatest in the south. For example, in Vanderburgh County sandstone thickness is greater than 200 feet. In the two branches of the West Baden Clastic Belt northeast and northwest of

MISSISSIPPIAN SYSTEM	BUFFALO WALLOW GROUP	GROVE CHURCH SHALE
		KINKAID LIMESTONE
		DEGONIA FORMATION
		CLORE FORMATION
		PALESTINE FORMATION
		MENARD LIMESTONE
		WALTERSBURG FORMATION
		VIENNA LIMESTONE
		TAR SPRINGS FORMATION
	STEPHENSPORT GROUP	GLEN DEAN LIMESTONE
		HARDINSBURG FORMATION
		HANEY LIMESTONE
		BIG CLIFTY FORMATION
		BEECH CREEK LIMESTONE
	WEST BADEN GROUP	CYPRESS FORMATION
		REELSVILLE LIMESTONE
		SAMPLE FORMATION
		BEAVER BEND LIMESTONE
		BETHEL FORMATION

Fig. 1

FIGURE 1. Chart showing stratigraphic nomenclature used in this report.

TABLE 1. Comparison of Chesterian Sand Belts.

	Length (in Indiana)	Width	Thickness
Waltersburg Formation	60 miles 100 km	2-5 miles 3-8 km	50-100 feet 15-30 m
Tar Springs Formation	60 miles 100 km	3-6 miles 5-9 km	100-125 30-40 m
Hardinsburg Formation	90 miles 145 km	2-9 miles 3-14 km	100-150 feet 30-45 m
West Baden Group	120 miles 190 km	3-10 miles 5-16 km	100-200 feet 30-60 m

Pike County (Figure 2), net sandstone thickness exceeds 100 feet. The width of belt sand in the West Baden is typically 8 to 10 miles in the southern area and is 3 to 5 miles in the northwestern and northeastern loci. Detailed information concerning sandstone distribution in the West Baden Group is contained in Sullivan (1972). In the West Baden rocks in Kentucky, Reynolds and Vincent (1972) have described a remarkable

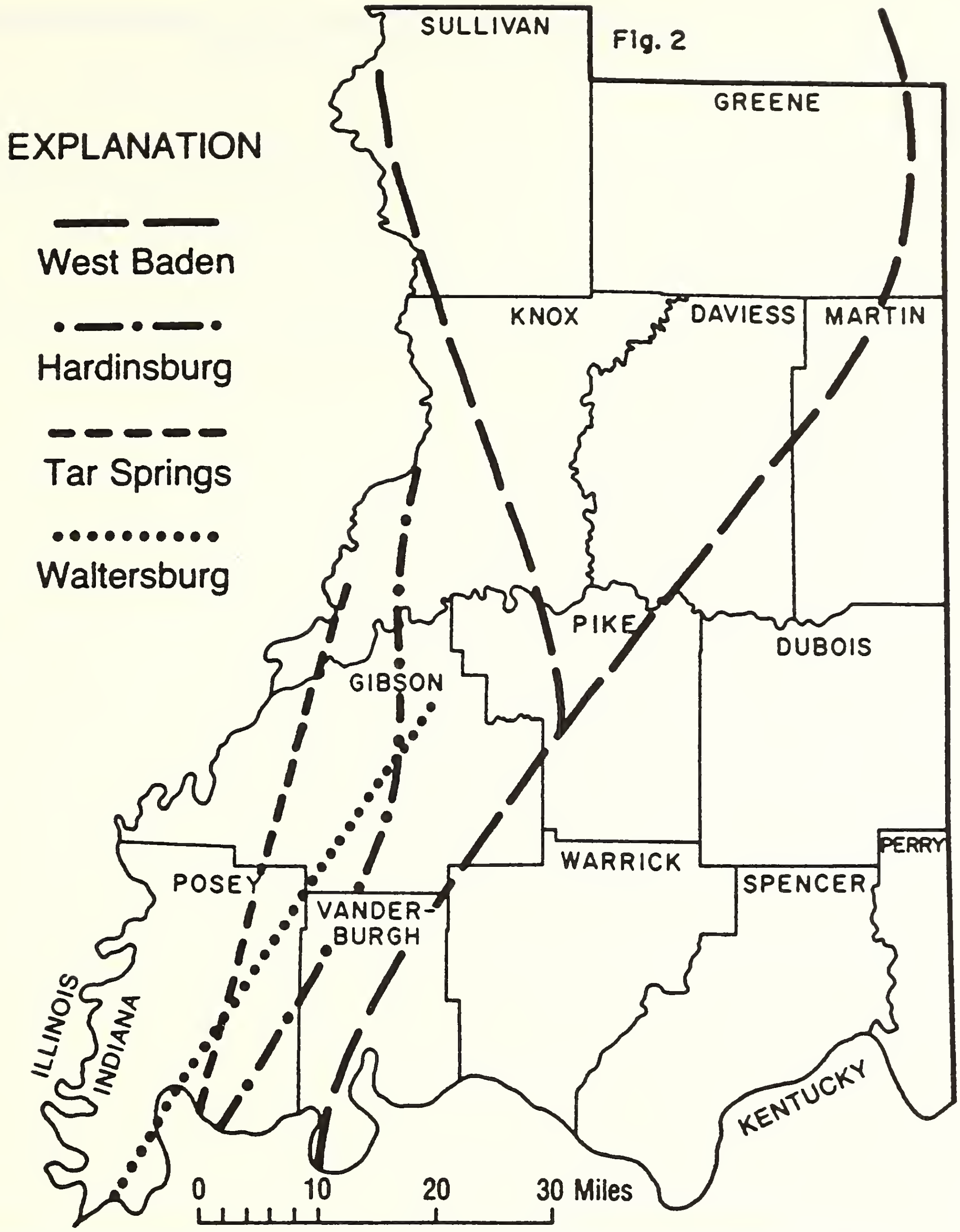

FIGURE 2. Map showing the axial trend of major belt sand bodies in the subsurface of Indiana.

body of belt sand, which is oriented east-west paralleling the structures of the Rough Creek Lineament.

Hardinsburg Formation

The trend of belt sand in the Hardinsburg Formation lies west of the trend of belt sand in the West Baden Group (Figure 2). The belt sand in the Hardinsburg of Indiana locally is more than 150 feet thick, and the zone of net sandstone thickness exceeding 100 feet is typically 2 to 5 miles wide (Droste and Horowitz, in press). This zone of belt sand extends southward into westernmost Kentucky. Another trend of belt sand in the Hardinsburg has been mapped in central southeastern Illinois (Potter, 1963, plate

IG). The major trend of Hardinsburg belt sand in Indiana closely parallels, but does not directly overlie, the structures of the Wabash Valley Fault System.

Tar Springs Formation

The trend of the major belt sand in the Tar Springs Formation of Indiana approximately parallels and is a few miles west of the trend of Hardinsburg belt sand (Figure 2). The net maximum thickness of sandstone in this belt is more than 125 feet in several places, and the zone of net sandstone thickness exceeding 100 feet is typically 3 to 6 miles wide (Droste and Keller, in press). The orientation of the major belt sand trend in the Tar Springs generally parallels and lies partly within the structural trend of the present Wabash Valley Fault System.

Waltersburg Formation

The axial trend of major belt sand bodies in the Waltersburg Formation crosses the trends of the belt sands in the Hardinsburg and Tar Springs (Figure 2), but belt sands of the Waltersburg are not as well developed throughout the entire trend as in older formations (Droste and Keller, in press). We classify the elongate sand bodies in the Walterburg in Indiana as belt sands, because net sandstone thickness exceeds 100 feet in several areas along the trend and net sandstone thickness exceeds 50 feet in widths as much as 5 miles throughout most of the axial trend (Figure 2). Shorter, narrower elongate sand bodies, called dendroids by Potter (1962, 1963), have been identified in other areas of Indiana beyond the limit of the Waltersburg belt sand zone. A more detailed treatment of sandstone in the Waltersburg is contained in Droste and Keller (in press). The orientation of the Waltersburg belt sand trend in Indiana more closely resembles belt sand trends mapped by Potter (1962) for the Waltersburg, Palestine, and Degonia rocks in Illinois than the orientations of belt sand trends of older Chesterian rocks in Indiana. This change in orientation suggests that some regional tectonic adjustment occurred between deposition of the Tar Springs and the Waltersburg belt sands.

DISCUSSION

More than two decades ago Swann (1964) suggested that rhythmic variations in rainfall were a major factor controlling low-latitude cyclical Chesterian sedimentation. A shift to wetter climate with increased rainfall resulted in a major increase in terrigenous sand and mud delivered to the basin. Consequently, siliciclastic deposition overwhelmed (smothered) low-latitude carbonate sedimentation. During times of reduced rainfall and reduced terrigenous input, the water in basin loci of deposition was less turbid, and carbonate sedimentation prevailed. Algeo and Wilkinson (1988) analysed Carboniferous sedimentary cycles and suggested that these cycles are consistent with, but not proof of, Milankovitch orbital modulations. Droste and Horowitz (in press) suggested that climatic variation, having periodicty of hundreds-of-thousands of years, generally was compatible with the periodicity of cyclical alternations of siliciclastic and carbonate depositional intervals recorded by Chesterian rocks in the Illinois Basin. Long-range Milankovitch orbital modulation as a control on climatic variation during Chesterian time is suggestive, but remains speculative.

Base level of deposition may also have been influenced by changes in global mean sea level in response to Carboniferous glaciations. Dating of Gondwana glaciations has improved markedly in recent decades and late Mississippian (late Visean-early Namurian) glaciation is known from South America and Australia (Veevers and Powell, 1987). However, the resolution of glaciations into corresponding sedimentary cycles or transgressive-regressive packages is only beginning. Inferred sea level curves (transgressive-regressive cycles) illustrated in Veevers and Powell (1987) bear little resemblance either in time or in number to the sedimentary cycles in the Chesterian of the Illinois Basin. Interestingly, Spencer and Demicco (1989) have modeled carbonate deposition on platforms which, given sufficient time, can generate cycles although sea level fluctuates only a few centimeters. Consequently, these authors note that comparable sea level changes resulting from subsidence (by any cause, for example, regional isostatic adjustments or adjustments resulting from sediment loading or compaction) could produce similar cyclic patterns.

Regional tectonic activity within the craton must have initiated basinal subsidence in order to provide room for the accumulation of Chesterian sediment. Intracratonic structrual adjustments resulting from tectonism at the edges of colliding plates probably elevated the source lands that provided sediment for the terrigenous components of Chesterian rocks. Transmission of forces, from cratonic edges to hundreds of kilometers within the North American craton, is well documented (Craddock and van der Pluijm, 1987) although poorly constrained chronologically within the late Paleozoic. The application of paleostress stratigraphy, discussed by Kleinspehn, Pershing and Teyssier (1989), would have similar problems with chronologic constraints if this methodology could be applied to the cratonic sediments of the Illinois Basin. The late Cenozoic collision of the Indian and Asian plates has produced large-scale structures in central Asia hundreds of kilometers from the junction of the two plates (Tapponier and Molnar, 1979). Basement rock adjustments, resulting from plate interactions, probably provided the impetus for most of the known linear structural and depositional features observed in the Paleozoic rocks of the Illinois Basin.

Interpretations of tectonic subsidence curves for the Illinois Basin (Heidlauf, Hsui and Klein, 1986; Klein and Hsui, 1987; Treworgy, Sargent and Kolata, 1989) are just now appearing, and the full array of factors influencing the Chesterian Series (Figure 1) is yet to be synthesized. In general, published tectonic subsidence curves are interpreted as representing the rise and fall (expansion and contraction of the deep-seated rock column) of the Illinois Basin above thermal sources in the earth's mantle. These thermal sources may result from stretching of the crust, the insulation effect of thick crust overlying hotter mantle, or thermal boundary effects between the crust and the mantle. Volcanic evidence exists for only a single post-Mississippian Permian event in the Illinois Basin. A proposed Mississippian thermal event is based on an analysis of the subsidence record of Mississippian and Pennsylvanian sediments in the Illinois Basin. Mantle plumes are a possible source of heat, but Quinlan and Beaumont (1984) have cautioned that the "pattern of arching....would obviously require a complex pattern of plate motions with respect to the plumes..." A comprehensive model for the origin of intracratonic basins remains an unsolved problem in geology.

Droste and Horowitz (in press) inferred from thickness and preservation that belt sandstones of the Hardinsburg Formation of Indiana formed by a concentration of quartz sand in low areas on the sea floor. During Hardinsburg time, the input of terrigenous clastics resulted principally from a postulated change to wetter climate and more rainfall in source areas surrounding the basin. Detrital quartz sands were funneled along sea floor "lows" where focused current activity produced much reworking. The lows formed in local areas where increased subsidence was controlled by minor tectonic adjustments in buried basement structures. These subtle tectonic movements were thought to be consistent with tectonic adjustments along the Wabash Valley Fault System (Indiana), the LaSalle Anticlinal Belt (Illinois), and the Rough Creek Lineament (Kentucky). Note that the scale of vertical movement necessary to accommodate belt sand accumulation (tens of meters) is a very small fraction of the lateral extent of either the cited structural features or the distance from the originating source of the structural movement or tectonism (hundreds of kilometers).

SUMMARY

Belt sand bodies of the Hardinsburg Formation in Indiana resulted from focused current action on quartz sands funnelled along sea floor lows (Droste and Horowitz, in press). These lows were located where locally increased subsidence resulted from subtle adjustments in basement structures. We infer that the belt sands in the West Baden, Tar Springs, and Waltersburg rocks in Indiana resulted from similarly controlled deposition and that their trends mark the changing loci of minor basement structural adjustments during Chesterian time. These trends generally parallel the tectonic adjustments that produced structures associated with the LaSalle Anticlinal Belt and Wabash Valley Fault System. The West Baden belt sandstones in Kentucky show clear alignment with the tectonic orientation of structures of the Rough Creek Lineament.

Belt sand body orientation within Chesterian rocks may not be the only indication of the orientation of subtle basement tectonics during the Carboniferous. Other features, such as the orientation of elongate sand bodies in Pennsylvanian rocks and the orientation of major stream systems formed on the pre-Pennsylvanian surface, may provide insight about other subtle tectonic adjustments in the cratonic area of the Illinois Basin. For example, Greb (1989) has attributed to structural control the orientation of stream drainage on the sub-Pennsylvanian surface in parts of western Kentucky.

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