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Preliminary paleomagnetic dating of the metalliferous (Zn–Pb rich), Stark black shale, Kansas City region, U.S.A.

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Abstract

The Stark metalliferous black shale is a member of the Dennis Formation, which is a cyclothemic limestone and shale unit in the Missourian (Upper Pennsylvanian) Kansas City Group. Paleomagnetic analysis of 96 specimens from 7 sites indicates that the characteristic remanent magnetization of the Stark Shale yields a Late Mississippian to Early Pennsylvanian age. This age is close to, but slightly older than, the Middle Pennsylvanian host rock age and implies that the metalliferous content of the shale is syngenetic in origin.

Keywords: Paleomagnetism; Metalliferous black shale; Pennsylvanian; Kansas City, Missouri

1. Introduction

The Stark Shale is a member of the Dennis Formation, which is a cyclothemic limestone and shale unit in the Missourian (Upper Pennsylvanian) Kansas City Group (Coveney, 1979; Fig. 1). The Stark Shale is enriched in heavy metals and elements such as Zn, V, U, Mo and Se (Coveney, 2003).

Leach et al. (2001) summarized studies about dating of Mississippi Valley-type Zn–Pb (MVT) deposits using high precision paleomagnetic, radiometric and fission track methods. Despite the broad agreement in many MVT districts, the timing of ore deposition remains debatable. Pan et al. (1990) reported initial paleomagnetic results from 7 sites in Mississippian carbonate rocks in the Warsaw Formation of the Tri-State MVT district ~100 km south of the study area. Symons et al. (2005) reported additional paleomagnetic data and concluded that the main hydrothermal MVT mineralization event in Tri-State was within the Middle Pennsylvanian to Middle Triassic time interval. Their study included 3 sites of Middle Pennsylvanian metalliferous black shales of the Hushpuckney Member near Kansas City, Missouri, that appeared to give a Middle Pennsylvanian paleopole. The aim of this study is to provide reliable magnetization ages for the metalliferous Stark Shale. If the sites show the primary age, it is considered that the remanence was a depositional NRM, i.e. a chemical remanent magnetization (CRM) of chemical or biotic origin, and/or a depositional remanent magnetization (DRM). Alternatively, a younger secondary remagnetization age would indicate that the mineralization was a CRM of hydrothermal origin.

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2. Geology

The study area is underlain by a flat-lying platform sequence of Mississippian and Pennsylvanian limestones and shales (Zeller, 1968) overlying a Precambrian basement that occurs at a depth of 300 to 800 m (Förster et al., 1988). The Middle and Upper Pennsylvanian rocks record cyclical sedimentation (Fig. 2). The Hushpuckney, Stark, Muncie Creek and Eudora black shales typically contain 1500–4000 ppm Zn in a belt of rocks extending from the Des Moines, Iowa, through the Kansas City area to northern Oklahoma. The metalliferous black portions of the Stark and Hushpuckney shales are both 15–45 cm thick (Coveney, 2003). Major constituents of the Stark Shale include clay minerals, quartz, calcite, dolomite, apatite, and organic matter. The predominant clay mineral is illite, and the remaining clay material comprises small amounts of kaolinite and chlorite (Coveney, 1979). The origins of the metals contained in the shales are quite complex. Some metals may have been derived from seawater (Holland, 1979). However, the main source of the metals would likely have been metal-rich basinal brines (Coveney, 2003). Judging from fluid inclusion studies and work on diagenetic clays, the shales have been impacted by hydrothermal processes (Hatch et al., 1976). Judging from textural relations, some enrichment of Zn appears to be syngenetic or early diagenetic, but, there is a distinct possibility for later additions of metals to these thin and well-jointed units (Coveney, 2003).

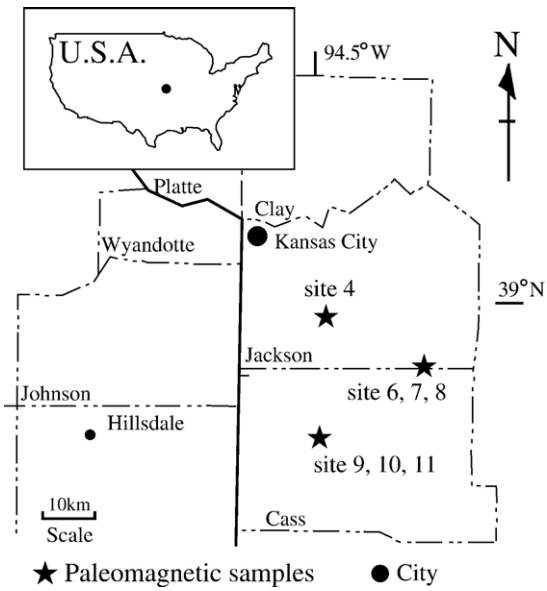

Fig. 1. Locality map showing the sampling locations (stars) of the Kansas City area, Missouri (modified from Ragan et al., 1996).

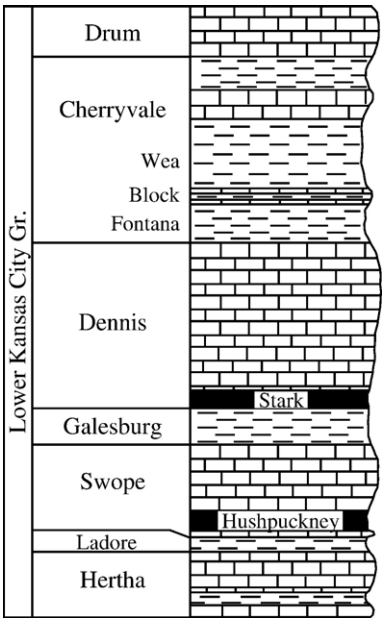

Fig. 2. Stratigraphic sequence of the lower Kansas City Group from Coveney (1979). For details see Gentile and Thompson (2004).

3. Methods and results

The collection comes from 7 sites (96 specimens) in the Stark Shale. The specimens' magnetic susceptibilities were measured on a Sapphire Instruments SI-2 meter, but showed little difference between sites (Fig. 3). The specimens' natural remanent magnetizations (NRM) were measured on a 2G Enterprises 755R DC-SQUID magnetometer with a sensitivity limit of $\sim 2 \times 10^{-6}$ A/m. The median NRM intensity of the specimens is 2.85×10^{-4} A/m. The site mean NRM directions are distributed southeastward away from the present Earth's magnetic field direction (Fig. 4A).

Two specimens from each site were chosen for alternating field (AF) demagnetization in 15 steps to 170 mT using a Sapphire Instruments SI-4 demagnetizer, and one specimen per site with the most intense NRM was chosen for low temperature demagnetization (LTD). LTD results are similar to AF demagnetization to 10 mT. Thus, LTD did not prove to be an effective demagnetization method for the Stark Shale. Thermal step demagnetization is not a practical alternative because of the high hydrocarbon content of the shale that usually exceeds ~17 wt.% organic carbon (Coveney, 1979). Hence, when a specimen is heated in the oven, not only may the fumes damage the equipment, but new magnetite

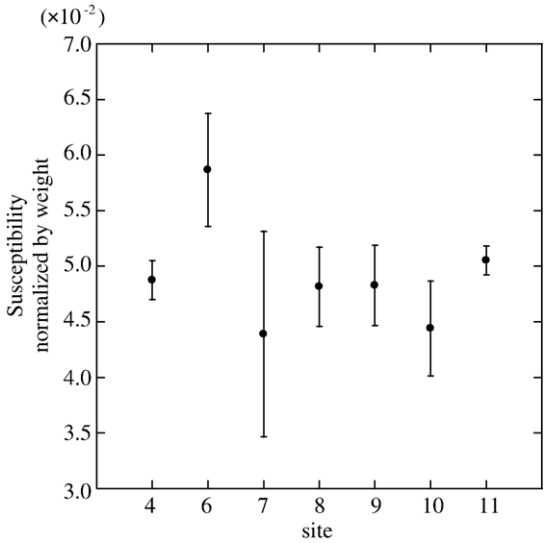

Fig. 3. Mean susceptibility of each sites.

is apt to grow also in the specimen because of the highly reducing internal environment. Based on the initial results, the remaining specimens were AF demagnetized in 9 steps to 170 mT. The characteristic remanent magnetization (ChRM) directions of the specimens were determined using principal component analysis (Kirschvink, 1980) for all sites and remagnetization circle analysis (Bailey and Halls, 1984) for site 11. Site and unit mean directions (Fig. 4B) were calculated following Fisher (1953) (Table 1). The unit mean ChRM direction is declination (D) = 137.0°, inclination (I) = 13.3° (α_{95} = 16.3°, k = 14.7). The preliminary pole position for the Stark Shale is at latitude 29.5°N, longitude 136.7°E, with semi-axes for the oval of 95% confidence of dp = 8.5° and dm = 16.6° (Fig. 5).

One specimen per site was pulse-magnetized in 12 steps up to 900 mT using a Sapphire Instruments SI-6 DC pulse magnetizer to define its acquisition of saturation isothermal remanent magnetization (SIRM), and

Table 1
Site mean remanence directions in the metalliferous Stark black shale

Site	Treatment	N, N_c	D, I		α_{95}	k
	mT		°	°	°	
4	100–170	10, 9	116.8,	18.6	13.2	15
6	100–170	16, 16	169.8,	3.6	3.6	159
7	40–80	14, 14	134.9,	13.5	4.1	93
8	100–170	14, 12	106.0,	15.5	7.2	37
9	30–60	12, 12	140.2,	10.9	5.2	71
10	30–60	14, 13	135.8,	12.9	4.2	96
11	0–170*	16, 10	154.0,	12.5		

*—Remagnetization circle.
N, N_c—Number of specimens measured for their NRMs and step demagnetised, and number of specimens used in site mean (also unit mean) ChRM. Mean declination (D), inclination (I) and radius of cone of 95% confidence (α_{95}) in degrees (°) and precision parameter (k) of Fisher (1953).

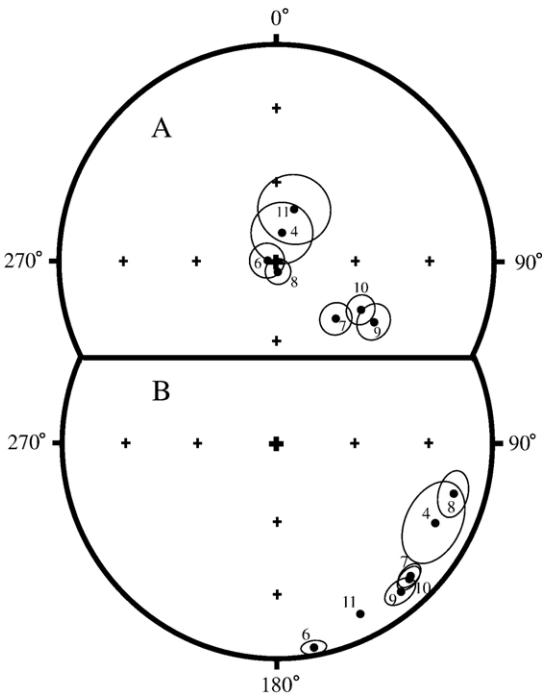

Fig. 4. Site mean directions.(A) of NRM, and (B) after demagnetization.

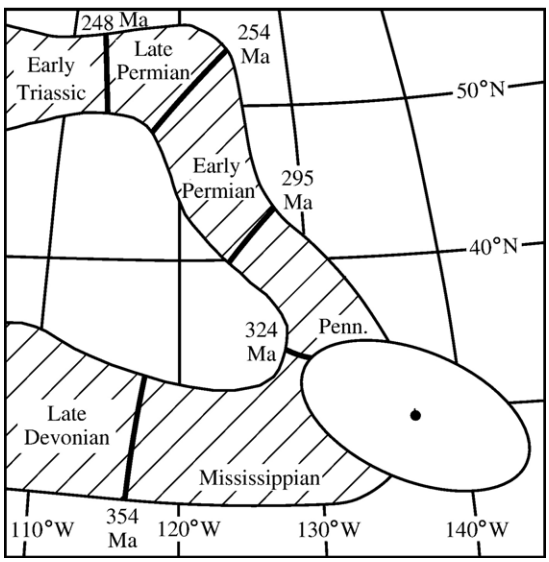

Fig. 5. Pole position for Stark Shale's mineralization with its oval of 95% confidence on the apparent polar wander path of Van der Voo (1993). Penn. = Pennsylvanian.

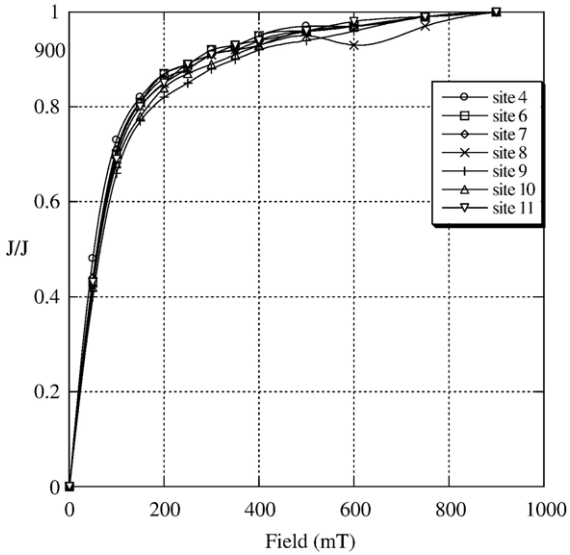

Fig. 6. SIRM acquisition curves.

then the SIRM was AF-demagnetized in 11 steps to 130 mT. The results show that the specimens contain single-domain (SD) magnetite as the main remanence carrier with ~20% of the NRM carried by hematite (Fig. 6).

4. Discussion

The shales have an extremely fine grain size, thus the magnetic minerals are apt to be SD magnetite, greigite and hematite. The SIRM acquisition test also indicates that the main remanence carrier is SD magnetite (Peters and Thompson, 1998). Thus, the specimens show the stable remanence directions up to ~130 to 170 mT that reside in magnetite with minor hematite.

The pole position for the Stark Shale falls on the Late Mississippian to Early Pennsylvanian portion of the apparent polar wander path (APWP) for North America of Van der Voo (1993) (Fig. 5), indicating that the shale has a similar magnetization age to its depositional age. This result indicates that the metalliferous content of the Stark Shale has a syngenetic origin. However, the oval of 95% confidence is large because of the small number of sites. Symons et al. (2005) reported paleomagnetic data for the Hushpuckney Shale. Its pole position is on the Middle Pennsylvanian portion of the APWP, which indicates that the ChRM was acquired during the Middle Pennsylvanian as a primary CRM during either deposition or initial compaction. Although the pole position of the Stark Shale is slightly older than the host rock age, it implies the ChRM was a primary remanence, i.e. a CRM of chemical or biotic origin, or a DRM. This result corresponds to the result from 3 sites in the Hushpuckney Shale.

In conclusion, the initial paleomagnetic results for black shales of the Kansas City area suggest that their anomalously high metal content is syngenetic in origin.

Acknowledgements

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