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FIELD, PETROGRAPHIC AND PALEOMAGNETIC INVESTIGATIONS OF AN ENIGMATIC SURFACE AT THE TOP OF THE ARGENTINE LIMESTONE, JOHNSON COUNTY, KANSAS: PART 1

by

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Introduction

The recognition and interpretation of important bounding surfaces in sedimentary sequences is an integral part of determining the overall depositional history and especially in understanding the sequence stratigraphic framework and relative sea-level history for the strata. In carbonate strata, subaerial exposure surfaces form either from allochthonous processes (e.g. tectonism, eustacy) resulting in relative sea-level falls and development of laterally extensive subaerial exposure surfaces (sequence boundaries), or from authochthonous processes that can result in high carbonate production and local aggradation of carbonate strata into the subaerial environment. Other types of surfaces formed in the submarine environment, such as flooding surfaces or hardgrounds, similarly can form from local or regional processes that may coincide with relative sea-level rises and highstands. Therefore, identification and correct interpretation of the different types of surfaces has implications for determining sea-level histories and potential correlations of strata over laterally extensive areas.

Recognition of subaerial exposure in marine carbonates can be difficult. Some of the reasons for the difficulty include: 1) many subaerial exposure facies undergo erosion and/or coastal to marine exposure and any evidence of subaerial weathering can be wiped out before being buried by new deposits (Esteban and Klappa, 1983); 2) both thickness of subaerial exposure facies and intensity of diagenetic processes are also controlled by hydrologic patterns, host lithology and climate (Esteban and Klappa, 1983); and 3) duration of subaerial exposure cannot be measured by the thickness of the weathering profile or by the intensity of diagenetic transformation (Esteban and Klappa, 1983). Thus, field evidence of subaerial exposure in carbonate rocks may be very subtle making recognition in the field difficult and multiple analytical techniques may be required in order to substantiate weak field evidence (e.g. Goldstein et al., 1991).

Purpose of the study

The Upper Pennsylvanian Argentine Limestone in Johnson County, Kansas, is a member of the Wyandotte Limestone within the Wyandotte depositional sequence (Figs. 1 & 2) (Watney et al., 1989). The sequence boundaries that separate major depositional sequences, such as the Wyandotte depositional sequence, are characterized by major facies changes and/or distinctive subaerial exposure surfaces (Fig. 2) (Watney et al., 1989) indicating fluctuations in relative sea level. However, many units within major depositional sequences display subtle surfaces that are not accompanied with major facies shifts; these surfaces may have formed from important higher frequency relative sea-level fluctuations. An irregular surface with a high concentration of iron oxides at the top of the Argentine Limestone, the focus of this study, may be an important surface within the Wyandotte depositional sequence but lacks diagnostic field evidence of forming subaerially or, alternatively, as a true submarine hardground. Concentration of iron oxides within a surface in carbonate strata, such as is associated with the upper Argentine surface, is one criteria commonly used to interpret a possible subaerial origin for the surface (e.g. Sarg and Lehmann, 1986; Franseen et al., 1989; Franseen and Goldstein, 1992). However, it is imperative that the origin and timing of the concentration of iron oxides of the surface be determined. Petrographic and paleomagnetic studies of the minerals associated with the iron staining can provide the neccessary information on the origin and timing of the concentration of iron oxides and therefore can aid in the interpretation of a submarine or subaerial origin of the surface.

The purpose of this study is to incorporate numerous methods and criteria to determine more clearly the origin of the enigmatic surface and its lateral extent. The study of the surface is divided into two parts. This study, Part I, focuses on petrographic identification of minerals associated with the high concentration of iron-oxides within the surface and the use of paleomagnetic data of the minerals to determine the origin and timing of the iron mineralization. An ongoing study, Part II, is focusing on field relationships and petrographic evidence to determine the paragenetic sequence and attempt to identify features that are diagnostic of either a subaerial or submarine origin of the surface.

Previous studies

Watney et al. (1989) found only equivocal evidence for subaerial exposure along the upper surface of the Argentine Limestone and speculated that the surface was a hardground or firmground that formed during reduced rates of sedimentation associated with marine flooding. Watney et al. (1989) designated the surface a parasequence boundary. Previous studies of the Argentine Limestone in Johnson County (e.g. Newell, 1935; Crowley, 1969; O'Connor, 1971) have not addressed the surface at the top of the Argentine Limestone.

Geologic Background

Regional

The Argentine Limestone, Missourian in age and a member of the Wyandotte Limestone, Kansas City Group, is an upper limestone of the Kansas City cyclothem and a shallowing-upward unit within the Wyandotte depositional sequence (Fig. 2) (Watney et al., 1989). The Quindaro Shale, a low radioactive core shale, underlies the Argentine Limestone and the Island Creek Shale, an outside shale, overlies the Argentine Limestone (Fig. 2). The Argentine Limestone throughout the study area is a broad algal bank composed mainly of phylloid-algal wackestone. This bank developed on the northwest flank of a deltaic platform within the Lane Shale (Crowley, 1969). The thickness of the Argentine Limestone locally exceeds 40 feet in this area. This thick accumulation occurred in response to a relative increase in accommodation space and normal circulation on the northwest side of the Lane delta (Watney et al., 1989).

Local

The surface at the top of the Argentine was identified at 5 localities (Fig. 3). One locality (F-1) is at the Frisbie Quarry (NE, NW, sec. 17, T.12S., R.23E.), two localities are along highway K-10 (K10E & K10W) east of Desoto (SW ,SW, sec.

36, T.12S., R.22E. and SE, sec. 6, T.13S., R.23E., respectively), one locality (C-1) is south of K-10 in the Cedar Creek residential development (NW, NW sec. 8, T.13S., R.23E.), and a fifth locality (O-1) is northwest of Olathe Lake (SW, SW, sec. 29, T.13S., R.23E.).

At the two K-10 sections, K10W and K10E (Fig. 3), the upper 0.5 meter of the Argentine Limestone contains medium to very dark-gray mottling (Fig. 4). Minor silicification and red mottling occurs in the upper dm. Watney et al. (1989) describe the upper surface as rising 2.1 meters from the east to just west of section K10E. Dm to cm local relief is common along this surface with rare overhangs associated with the microtopography (Fig. 5).

At locality K10E, the Island Creek Shale was described by Watney et al. (1989) as onlapping onto the Argentine Limestone. Although onlapping terminations of beds, as typically used to define onlap in sequence stratigraphic terminology, are not necessarily evident at this location, it is clear that the Island Creek thickness decreases from about 1.5 m to pinchout in a westward direction. At the K10E locality, the Island Creek Shale is composed of a basal gray siltstone and coarse-grained encrinite overlain by gray fossiliferous shale (Watney et al., 1989). The basal encrinite is interpreted to represent a flooding event with subsequent deepening and deposition of clay below wave base (Watney et al., 1989). One mile west of K10E, at section K10W, the Island Creek Shale is a 0.5 m thick dark-gray shale.

At the Frisbie Quarry (Figs. 6 & 7) and Olathe sections (F-1 and O-1) silicification of the upper Argentine surface was not observed and red mottling was more poorly developed compared to the K-10 sections. The upper surface of the Argentine Limestone contains minor silicification but no red mottling at locality C-1. Instead the upper dm to 0.5 m is a yellow-brown color. Dm-scale microtopography on the upper surface of the Argentine Limestone is common at all 5 localities designated in Fig. 3.

Methods

Three localities (K10W, K10E, and F-1) were measured and sampled, two other localities sampled (C-1 and O-1), and numerous other outcrops visited at the reconnaissance level in northwestern Johnson County (Fig. 3). Twenty-five hand samples were collected for polished slab, petrographic, cathodoluminescence, and stable-isotopic analyses. Forty 2 cm-diameter cores were collected for paleomagnetic studies using a portable gasoline-powered drill. From these samples, 90 samples were cut from a trim saw. Polished thin sections were produced from twenty-five of the samples and observed under a petrographic microscope by both reflected and refracted light to identify opaque minerals, their abundances and their paragenetic relationships. Reflected light was used for the identification of pyrite. Hematite and goethite were identified using the "blue card" method of R.L. Folk (Farr and Gose, 1991) by which a thin section is placed on a blue card and observed with reflected light. This technique accentuates orange and red hematite and yellow goethite.

Prior to demagnetization studies, samples were stored in a magnetically shielded room for approximately three-weeks. Magnetic remanences were measured for four samples using a two-axis ScT cryogenic magnetometer in a shielded room. Thermal demagnetization and measurement of remanences was carried out by 25° C incremental increases of temperature until the remanences decayed below the detection limits of the magnetometer or became unstable.

Susceptability measurements of 25 samples helped to identify abundances of magnetically susceptable minerals in the three measured stratigraphic sections. Acquisition of isothermal remanent magnetization (IRM) for 7 samples from section K10W aided in the identification of magnetic phases.

Petrographic Results

Preliminary Paragenetic Observations

Reconnaissance petrographic studies were carried out to determine the general paragenetic sequence and to identify features that could characterize the surface as an exposure surface or submarine hardground. No strong evidence of subaerial exposure, such as rhizoliths, pendant cements, laminated crusts or microkarstic features were identified. Rip-up clasts of red hematitic Argentine Limestone are present in grainstones of the Island Creek at locality K10E suggesting pre-Island Creek formation of red mottling. However, acquisition of the red coloration could be a fabric selective process and may have occurred post-Island Creek deposition. Within the Argentine Limestone, skew-plane fitted cracking is common with a bias towards vertical to subvertical orientation of cracks. Also common to phylloid-algal wackestones are fitted-fabric cracks lined with bladed cements and finally equant spar. These cracks may be associated with autobrecciation resulting from subaerial exposure or, alternatively, compaction (Shinn et al., 1983). A possible paragenetic sequence for the features observed to date at the upper Argentine surface is as follows: 1) cracking due to subaerial exposure after Argentine deposition and prior to Island Creek deposition; 2) bladed cements precipitated during marine inundation; and 3) equant spar precipitation during late burial or from late-stage meteoric waters. Rare antipendant palisade-like spar cements were identified in a polished slab, suggesting possible formation under vadose conditions. However, at this point, the timing of precipitation of those cements is unknown and they may be very late-stage cements. Several thin sections were observed petrographically with cold-cathodoluminescence as an aid in identifying pendant cements; no pendant cements were identified.

At localities K10E and C-1 the upper Argentine surface is typically encrusted by the phylloid-algae *Archaeolithophyllum missouriense* suggesting that the surface is related to a hiatus in deposition and formed as a submarine hardground.

The above discussion represents only preliminary observations of diagenetic features and the paragenetic sequence associated with the upper Argentine surface. Additional detailed diagenetic and paragenetic studies are currently being conducted to further clarify the origin of the upper Argentine surface.

Opaque minerals

A high concentration of pyrite occurs in the upper meter of the Argentine Limestone in samples studied from locations K10W, K10E and C-1. This high concentration of pyrite is thought to give the upper 0.5 m of the Argentine Limestone its gray coloration in outcrops K10W & K10E along highway K-10 (Fig. 4). The pyrite is most abundant as a replacive or displacive mineral in micritic matrix but also replaces allochems and rarely replaces cements. Pyrite also occurs in minor amount throughout the remaining Argentine Limestone.

Hematite is abundant in the upper few decimeters of the top of the Argentine Limestone at localities K10W, K10E, F-1, and O-1. Ten miles separates these locations. In addition, well below the top of the Argentine Limestone small cm-scale irregular patches of red colored micrite occur locally. These particular red-stained patches were not studied by petrographic methods. The hematite in the upper Argentine Limestone replaces pyrite. The replacement, at least locally, forms halos of hematite surrounding hairline fractures likely associated with modern exfoliation (Fig. 8). This evidence supports the hypothesis that the hematite is a recent addition to the Argentine Limestone.

Goethite occurs in high concentrations in the upper few centimeters of the Argentine Limestone at the Cedar Creek golf course (C-1) south of K-10. The relationship to pyrite is similar to that described for hematite and is also interpreted to be a recent replacement of pyrite. Goethite is common throughout the remaining Argentine Limestone.

A black, very finely crystalline (<5 microns) opaque mineral was observed in most thin sections but mineralogical identification is uncertain. It is suspected to be pyrite with the crystal size too small for resolution of its gold color, alternatively, it is possible this mineral is magnetite. Scanning electron microscopy should be used in any future studies to aid in its identification.

Paleomagnetic Results

Introduction

Iron oxides such as hematite and goethite can form on and beneath an exposed rock surface due to chemical weathering of iron-bearing minerals during soil formation (Schwertmann, 1985). Association of these iron oxides with rock surfaces displaying erosion has been used as criteria in identification of subaerial exposure (Sarg and Lehmann, 1986; Franseen et al., 1989; Franseen and Goldstein, 1992). During formation these iron oxides can lock in a magnetization that is aligned with the existing polarity of the earth's magnetic field, either normal or reversed. If preserved, this polarity can be used to help demonstrate the timing of the formation of the iron oxides. Keller and Gehring (1992) used the polar directions of remanent magnetization carried by iron oxides in late Cretaceous limestones of the southeast Pyrenees, Spain, to elucidate the timing of their formation during exposure and weathering.

In this study, magnetic and petrographic data are used to deduce the timing of the formation of iron oxides at the upper surface of the Argentine Formation.

The polarity of the earth's magnetic field was reversed during the Late Pennsylvanian/Late Permian (Lu et al., 1990). This long period of reversed polarity is called the Kiaman long reversed polarity interval. Magnetic minerals deposited or formed chemically during that time can retain a magnetic remanence aligned with that reversed field which is detectable in the laboratory. If the formation of hematite in the upper surface of the Argentine occured during the Missourian, then the hematite should retain a reversed polarity. Conversely, recently formed hematite should have a normal polarity. Paleomagnetic evidence alone will not yield conclusive evidence for the timing of formation of iron oxides. However, corroboration with petrography can strengthen any paleomagnetic evidence.

Paleomagnetic techniques can also be utilized to identify magnetic minerals. This is important because the presence of hematite, goethite, magnetite or pyrite can lead to different interpretations as to the history of the rock. Any of these minerals could be detrital in origin and if identified as detrital they are not generally indicative of the chemical conditions under which the enclosing sediments were deposited. Magnetite can be biogenic in origin and associated with aerobic marine carbonate environments (McNeill, 1990). Any of the iron oxides can be formed in and concentrated in soils (Schwertmann, 1985; Maher & Taylor, 1988). Pyrite indicates conditions of low Eh and can form both in surface deposits, such as those associated with peats, or in marine deposits under anerobic conditions. Magnetite and pyrite can also form as a late stage mineral in the deep subsurface (McCabe et al., 1983; Lu et al., 1990). In general, however, for iron minerals formed chemically in a surface or near surface environment, iron oxides are indicators of oxidizing conditions (exposure) and pyrite indicates reducing conditions (very wet or submerged).

Isothermal Remanent Magnetism

Isothermal remanent magnetism (IRM) is the magnetism that remains after a strong field is applied to a rock sample for a short period of time. Coercive properties can be determined for a rock sample by studying IRM vs applied field strength cross plots and aid in identification of magnetic minerals. Magnetite has a low coercivity and goethite and hematite a high coercivity. Coercivities of six samples from the Argentine Limestone and one sample from the lower Farley were studied from section K10W. Sample 7.7c from the base of the lower Farley Limestone shows (Fig. 9a) that this limestone is dominated by a low coercivity mineral, probably magnetite. The sample saturated by 200 mT. This is the only sample in which magnetite appears to be the predominant carrier of the remanent magnetism. A sample from just below the upper surface of the Argentine Limestone (7.2b) in which red mottling is common shows (Fig. 9b) that the sample is dominated by a high coercivity mineral, hematite, based on petrography and the highly coercive behavior. The sample did not reach saturation by 1000 mT. A weak plateau between 1 and 150 mT suggests that a small amount of a low coercivity mineral is present, possibly magnetite. Another sample (7.1b) from the red mottled micrites just below the upper surface of the Argentine Limestone yields a steep increase in IRM (Fig. 9c) between 0 and 150 mT indicating a low coercivity phase, possibly magnetite. The shallow increase of IRM between 550 and 1000 mT indicates the presence of a high coercivity phase, hematite. Four other samples below the upper surface of the Argentine Limestone show (Figs. 9d-g) IRM plateaus between an early buildup in IRM and 500 to 700 mT. This suggests that the samples have a low coercivity component, possibly magnetite, and a higher coercivity component, goethite, based on petrography and high coercivity behavior.

Susceptibility

Magnetic susceptibility is the magnetizability of a substance and can be used to identify the presence of minerals that can be magnetized. Modern soils may have associated enhanced susceptibilities due to relatively high concentrations of the ferrimagnetic minerals magnetite and maghemite (Singer and Fine, 1989). Increases in magnetic susceptibility have been documented in association with paleosols of late Tertiary loess deposits which are due to relatively high concentrations of magnetite within the soil profile (Kukla et al., 1988; Liu et al., 1992). Measurements in samples from sections K10W, K10E and F-1 show that the upper surface of the Argentine Limestone has a relatively high susceptibility when compared to the underlying lithologies of the Argentine Limestone (Fig. 10). The high concentration of hematite in this Pennsylvanian surface is probably responsible for this anomaly. But this does not preclude a pedogenic origin for the hematite as concentrations of hematite within a soil can be preserved and produce enhanced susceptibilities such as that reported for relatively high concentrations of magnetite and maghemite in modern and ancient soils.

Saturation Isothermal Remanence

Saturation isothermal remanent magnetization (sIRM) is the maximum intensity of remanent magnetization that can be achieved when a strong field is applied to a rock sample. Increasing the intensity of the field beyond this level will not result in a strengthening of the remanent magnetization of the sample, it has reached saturation. A plot (Fig. 10) of sIRM for the seven samples shows an anomalous high sIRM at the top of the Argentine which corresponds to the susceptibility anomaly. This is due to a high concentration of high coercivity minerals, probably hematite, as indicated by petrography.

Characteristic Remanence

Natural remanent magnetism (NRM) is remanent magnetism present in a rock sample prior to alteration in the laboratory. NRM's of four samples from the upper surface of the Argentine Limestone (Figs. 11-14) were weak ranging from 2.0-6.7 10^{-8} mA/m. Characteristic remanent magnetization (ChRM) is the highest-stability component of NRM that is isolated by step-wise demagnetization. Results show all four samples have a normally polarized ChRM. However, sample 7.1a (Fig. 12) shows movement of inclination vectors towards the reversed field up until 200° C, possibly indicating a strong normal component is removed from a weak reversed remanence. After 250° C the remanence appears to become unstable, possibly due to the formation of new iron oxides at these relatively higher temperatures. Nonetheless all four samples appear to be dominated by a normal component.

Interpretation

Whether the ChRM of the four samples of red mottled micrites from the upper surface of the Argentine is a modern viscous remanent magnetism (VRM) or chemical remanent magnetism (CRM) is uncertain. VRM is a remanent magnetization that is acquired over a long period of time during exposure to weak magnetic fields. CRM is acquired by ferromagnetic minerals that form due to chemical processes (eg. diagenesis) below their blocking temperatures. Petrographic relationships and coercivity behaviors would support a strong CRM overprint, that is, hematite as the principle carrier of magnetism. However, it is possible that a minor component of original detrital, biogenic and/or secondary (McCabe et al., 1983) magnetite is present in the samples. In conclusion, the petrography, coercive behavior, and demagnetization of remanent magnetism suggest that the hematite in the upper surface of the Argentine Limestone is modern.

If the hematite in the upper Argentine is modern, then an important question remains: what is the timing and process in which pyrite, the precursor to the hematite, was concentrated within the upper Argentine surface? Two possible scenarios are suggested. It is possible that the concentrations of pyrite at the top of the Argentine Limestone occured in a submarine environment during a hiatus in deposition prior to Island Creek deposition. Fürsich et al. (1992) describe concentration of iron minerals in hardgrounds of the Jurassic of India. Alternatively, the presence of a lithology dominated by a low coercivity mineral (likely magnetite) at the base of the Lower Farley Limestone and its suspected presence as a minor component in the underlying Argentine Limestone allows one to speculate that the Argentine Limestone originally contained a higher concentration of magnetite (detrital and/or biogenic) that was altered to other iron mineralogies (hematite) due to early exposure. During subsequent transgression the iron oxides could have been reduced to iron sulfide. Finally, during recent exposure, the iron sulfides could have been oxidized back to iron oxides. A similar scenario has been proposed for a concentration of reduced iron in a Late Ordovician siliciclastic exposure surface by Driese et al. (1992). We conclude, at this time, that the timing and process in which pyrite was concentrated within the surface is equivocal.

Conclusions

The results of this part of the study of the upper Argentine surface and related features suggest that the anomalous concentration of iron oxides at the top of the Argentine Limestone is a recent event. In the absence of clear field and petrographic evidence of subaerial exposure it is suggested that the microtopography and concentration of reduced iron (pyrite) at the top of the Argentine is related to formation of a submarine hardground during a hiatus in deposition, as suggested by Watney et al. (1989). However, the possibility of subaerial exposure should not be ruled out pending the completion of the detailed diagenetic, paragenetic and geochemical portion of the study. This study demonstrates that magnetic susceptibility profiles can be a quick and useful means of quantitatively characterizing Late Pennsylvanian surfaces and aid in correlation (Fig. 10). Paleomagnetic studies can aid in determining timing of iron oxide concentrations within a carbonate surface, a feature commonly used to interpret subaerial exposure origin for the surface. Thus this study shows that combined petrographic and paleomagnetic studies can provide a useful means to elucidate the origin of enigmatic surfaces.

Acknowledgements

M.R. Farr provided many insights into paleomagnetic techniques and interpretation of paleomagnetic data.

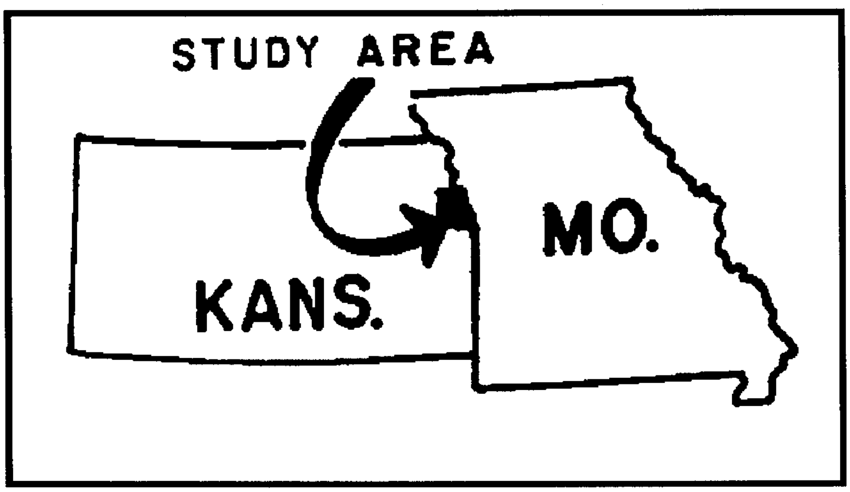


Figure 1. Location map of study area.

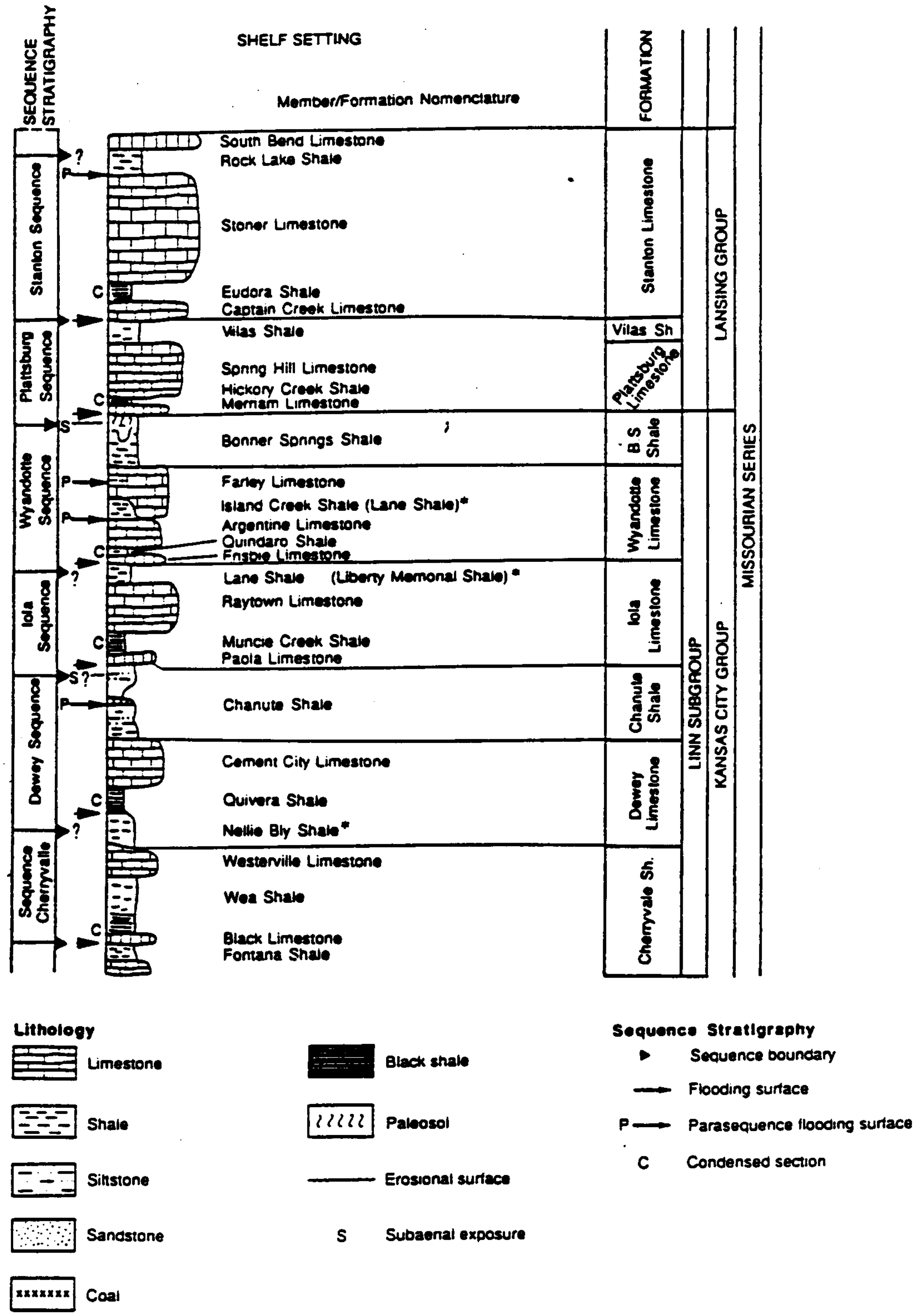


Figure 2. Stratigraphic section of Kansas City-Lansing Groups (from Watney et al., 1989).

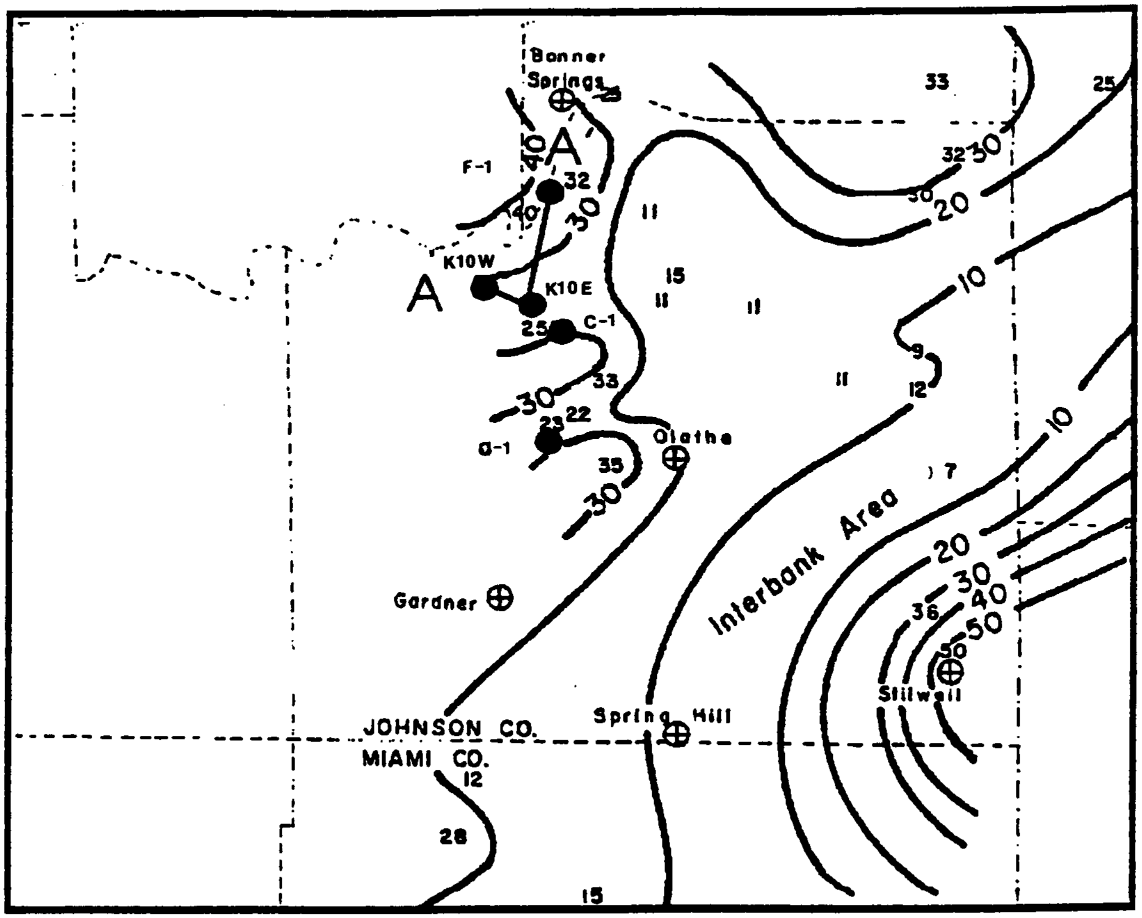


Figure 3. Isopach map of Argentine Limestone Member (from Crowley, 1969). Note thickened areas at Olathe-Bonner Springs separated from thickened area at Stilwell by thinner interbank area. Also shown are sample localities and location of cross section A-A'.

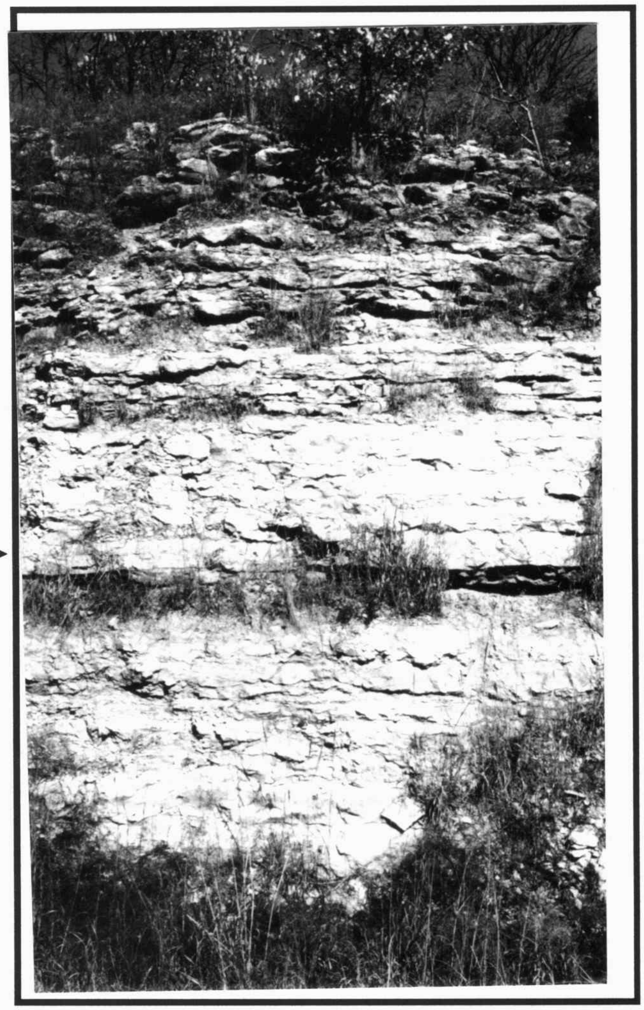


Figure 4. Argentine Limestone and Farley Limestone on north side of highway K10 just northwest of section K10E. A thin recessive shale of the Island Creek separates the Argentine from the overlying Lower Farley Limestone.

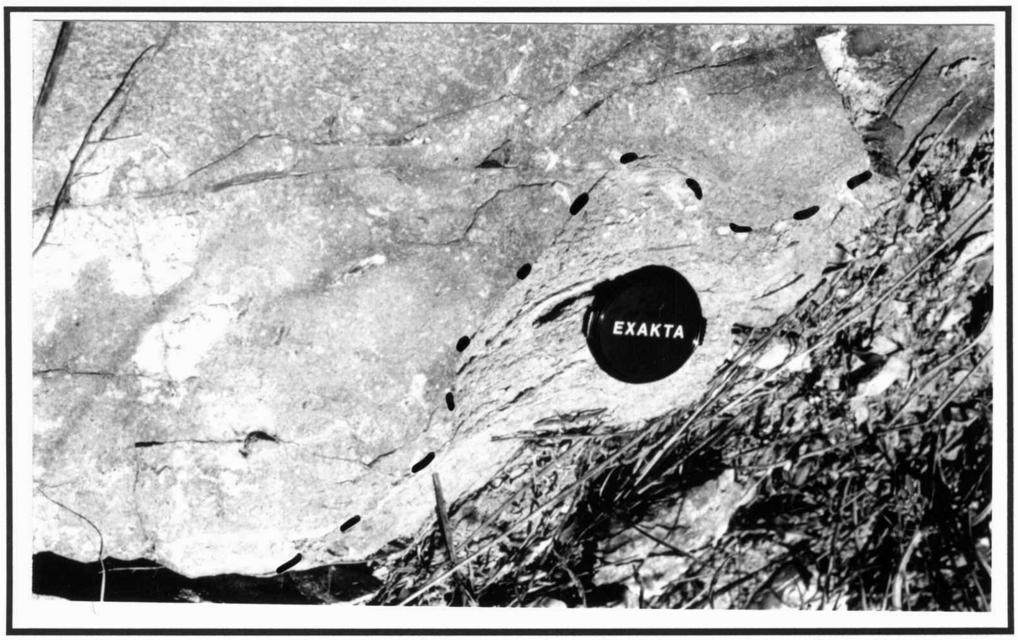


Figure 5. Contact between Island Creek and Argentine on north side of highway K-10 just northeast of section K10E. Crinoidal grainstones of the Island Creek fill dm-scale eroisional scour on top of the Argentine. Dashed line indicates contact.

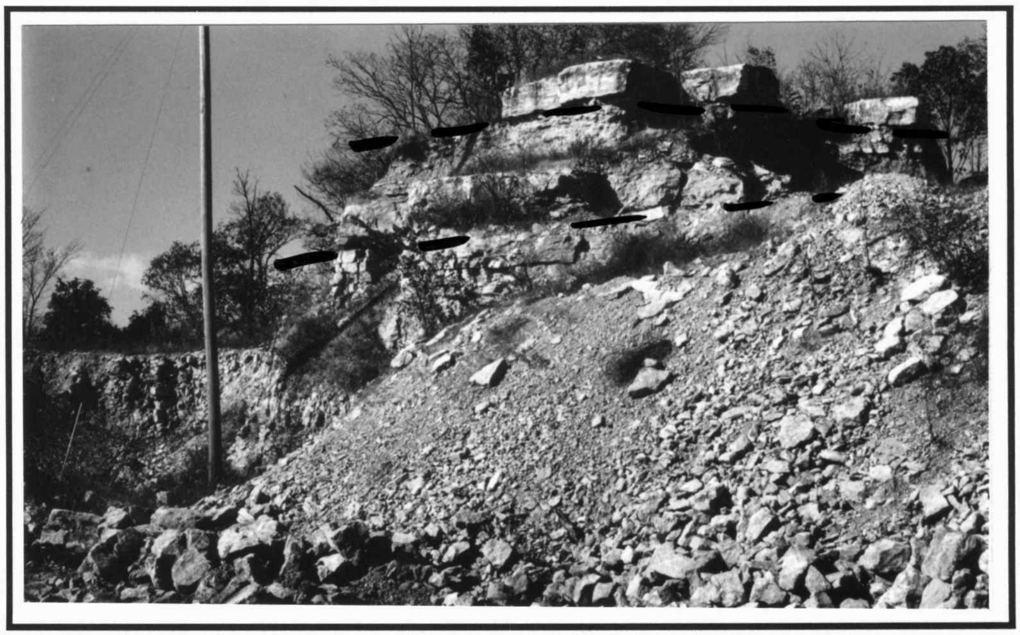


Figure 6. Western wall of Frisbie Quarry (Section F-1) showing Argentine, Island Creek and Farley Limestone. Dashed lines show Agentine-Island Creek and Island Creek-Farley contacts. The Island Creek is interpreted to contain a limestone member which occurs above a ruddy and irregular surface of the Argentine.

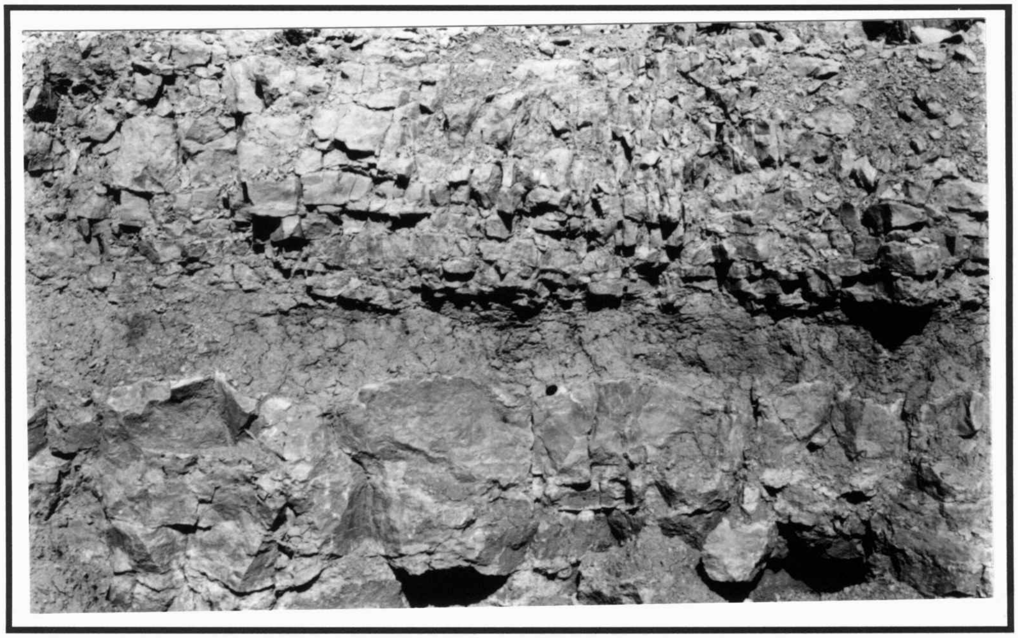


Figure 7. Contact between Island Creek and Argentine at Frisbie Quarry (Section F-1). Ruddy and irregular upper surface of Argentine has similar lithologic and paleomagnetic characteristics as the surface studied in detail at K10W and K10E. The thin shale and limestone above this surface is interpreted to be Island Creek.

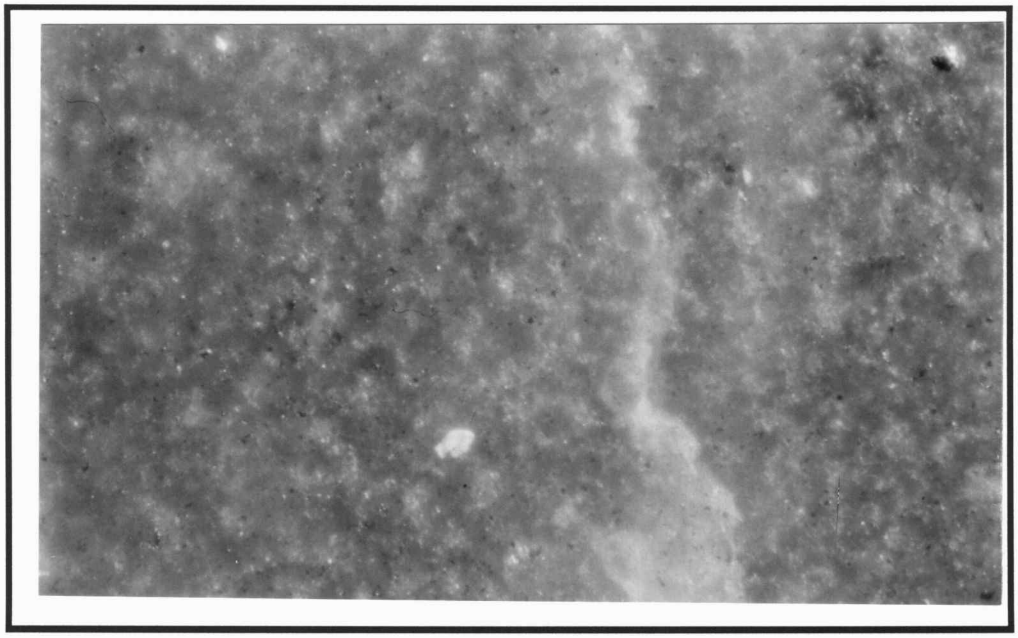


Figure 8. Photomicrograph in reflected light of lime wackestone from the upper surface of the Argentine Limestone. The micrite has a dense concentration of pyrite, however, right of center is a hairline fracture surrounded by a halo of hematite which replaces pyrite. The fracture is interpreted to be an exfoliation fracture associated with modern weathering of the outcrop.

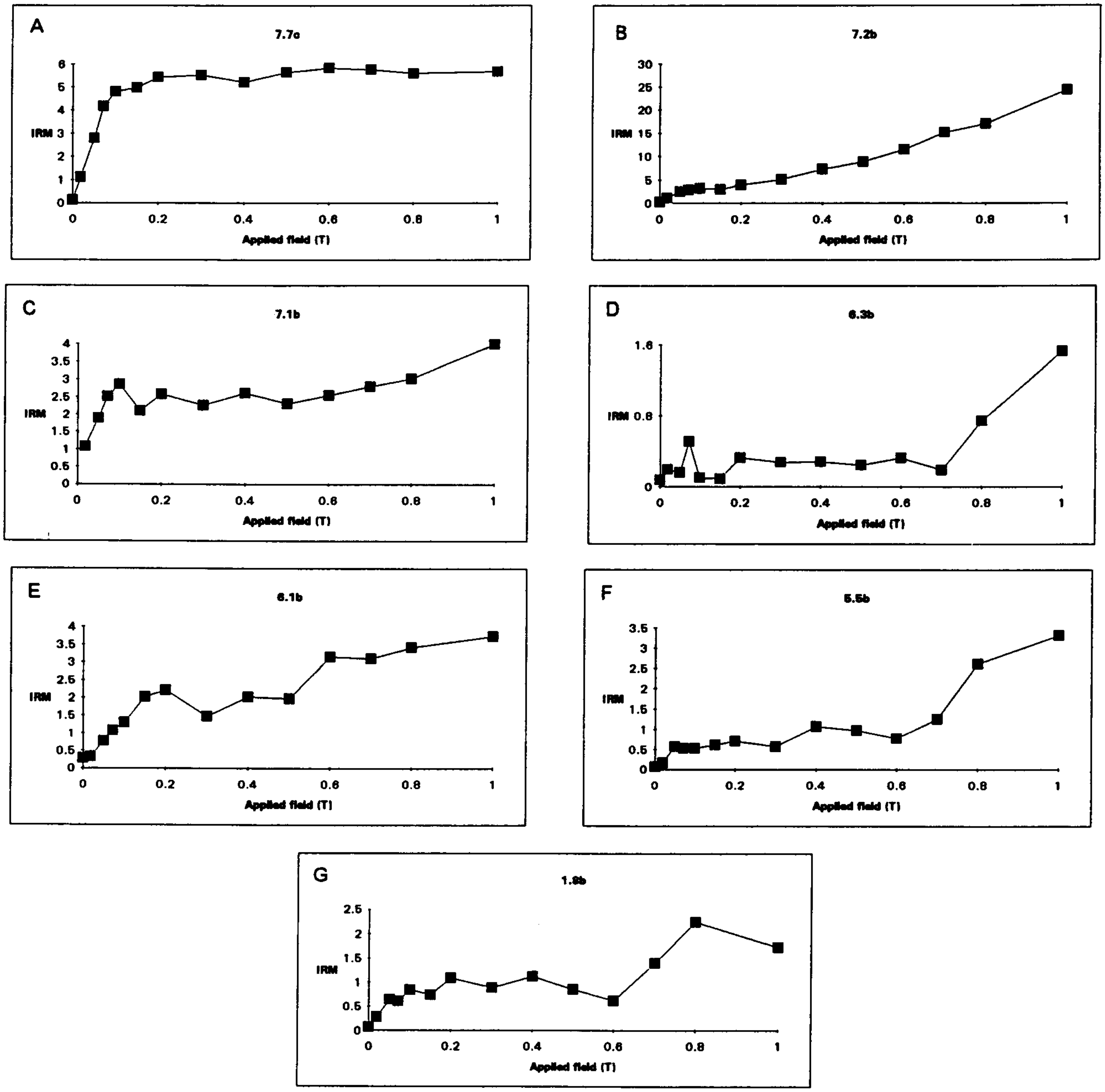


Figure 9. Isothermal remanent magnetization (IRM) plots of samples from the Farley and Argnetine Limestones at section K10W. a) base of Farley Limestone dominated by a low coercivity phase, b-g) all samples are from the Argentine limestone and dominated by a high coercivity phase, c-g express the influence of a low coercivity phase. Sample numbers in upper center of each plot indicates meters above base of section.

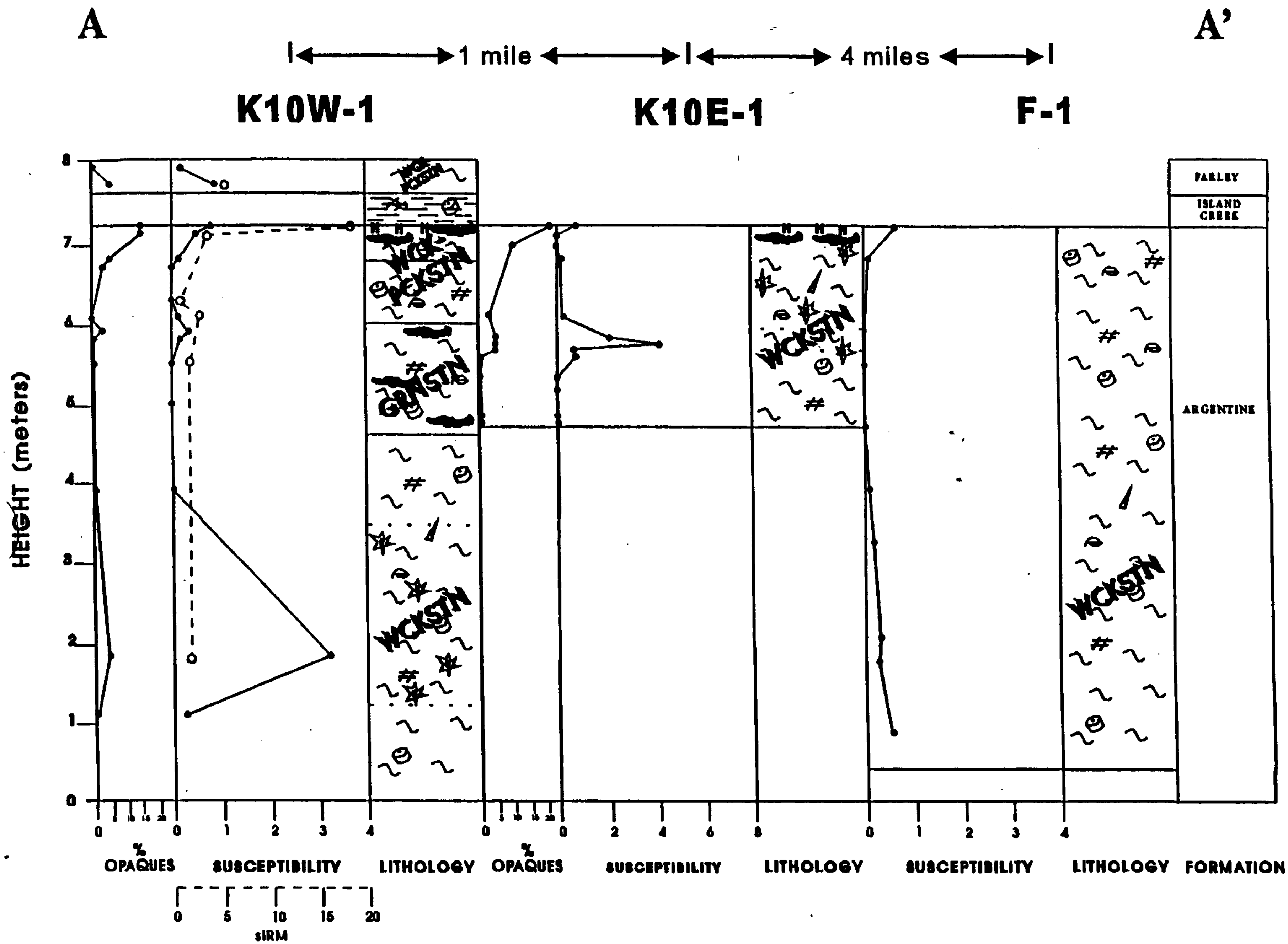
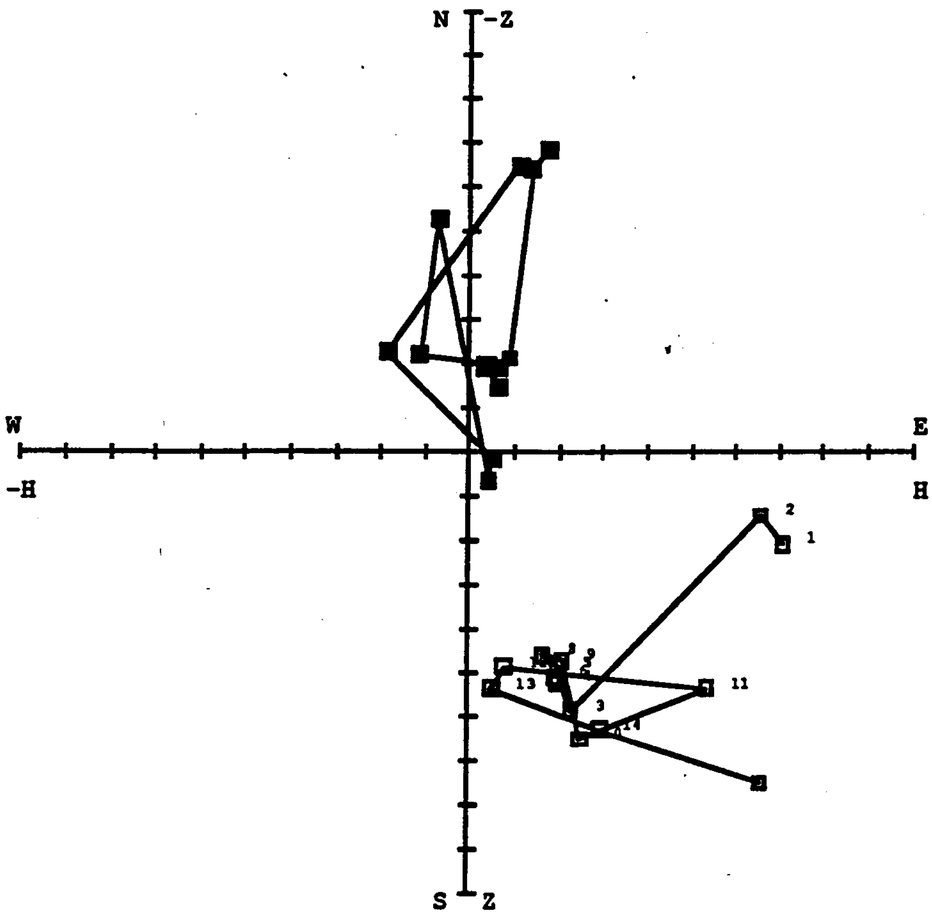


Figure 10. Cross section A-A' (see Figure) of Argentine lithologies and rock magnetic properties. Per cent opaques includes both opaques and red and yellow-orange translucent minerals.

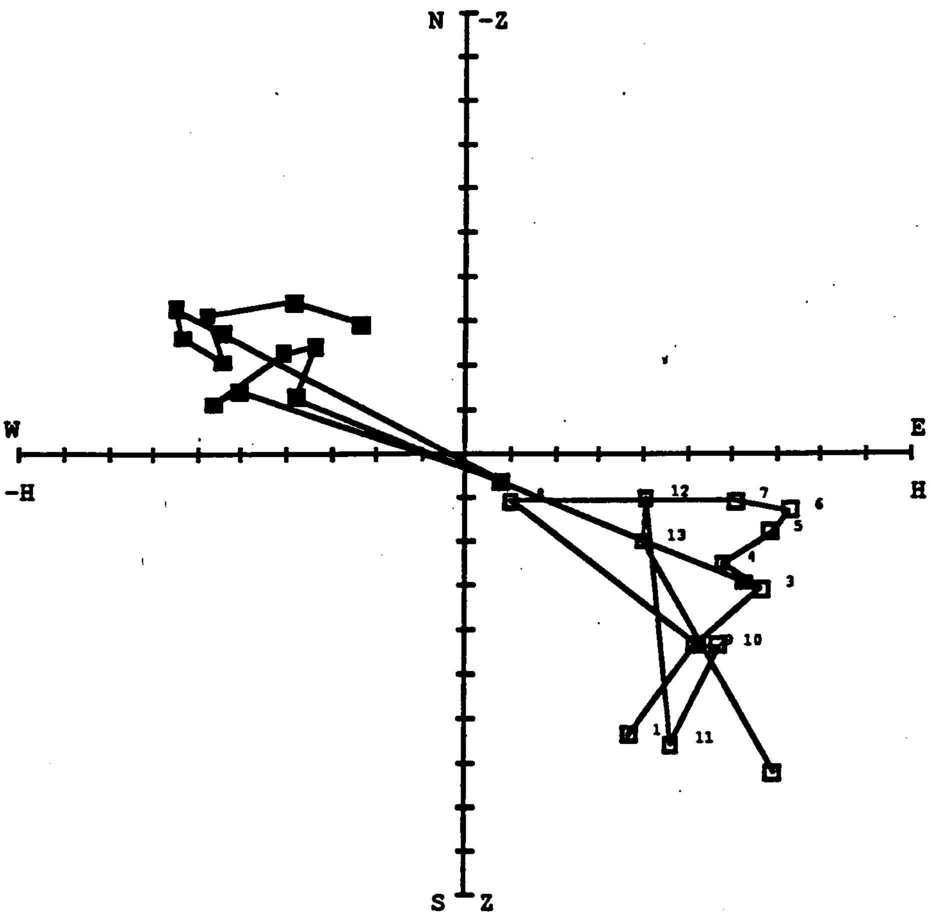


W7.2D

	STEP	DECL	INCL	mA/m
1	NRM	13.9	16.4	0.006
2	100	11.9	12.1	0.006
3	125	21.6	68.5	0.005
4	150	19.2	68.8	0.005
5	175	17.1	67.9	0.004
6	200	8.0	69.0	0.004
7	225	8.5	67.7	0.004
8	250	24.5	70.5	0.004
9	300	11.6	66.4	0.004
10	325	333.1	69.1	0.006
11	350	352.3	45.0	0.006
12	375	146.8	81.2	0.004
13	375	107.5	84.6	0.004
14	400	320.9	65.1	0.006
15	425	9.2	48.7	0.0091

OPEN SYMBOLS=VERTICAL PLANE
CLOSED SYMBOLS=HORIZONTAL PLANE

Figure 11. Orthogonal diagram (A-Z plot) showing a rather unstable behavior of magnetic remanence during stepwise demagnetization of a hematitic lime wackestone (sample 7.2d) from the upper surface of the Argentine Limestone at section K10E. Characteristic remanent magnetism appears to be normal.

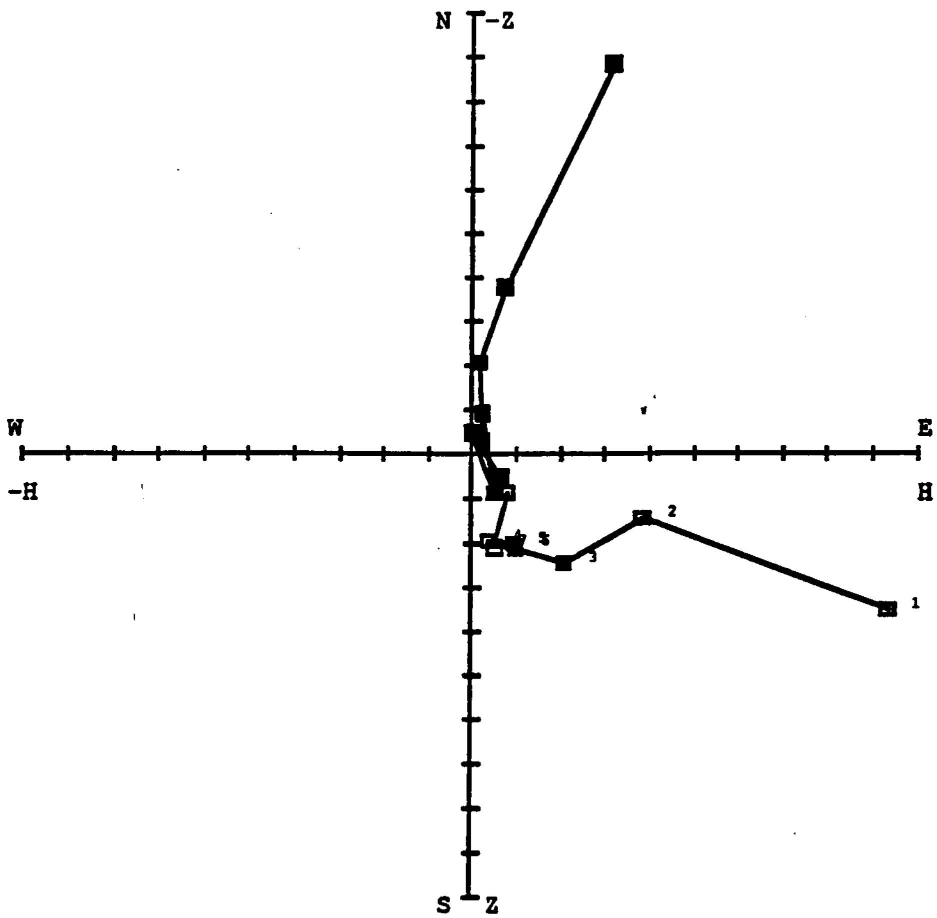


W7.1A

	STEP	DECL	INCL	mA/m
1	NRM	320.8	59.5	0.002
2	100	311.9	40.4	0.001
3	125	298.6	25.0	0.002
4	150	290.9	23.6	0.001
5	175	292.6	14.8	0.002
6	200	297.0	9.8	0.002
7	225	296.7	10.1	0.001
8	250	129.2	46.7	0.000
9	300	285.8	39.4	0.001
10	325	281.4	37.2	0.002
11	350	299.3	54.8	0.002
12	375	305.7	13.4	0.0012
13	400	288.6	26.8	0.0012
14	425	115.3	46.1	0.0028

OPEN SYMBOLS=VERTICAL PLANE
CLOSED SYMBOLS=HORIZONTAL PLANE

Figure 12. Orthogonal diagram (A-Z plot) showing a rather unstable behavior of magnetic remanence during stepwise demagnetization of a hematitic lime wackestone (sample 7.1a) from the upper surface of the Argentine Limestone at section K10E. Characteristic remanent magnetism appears to be normal.

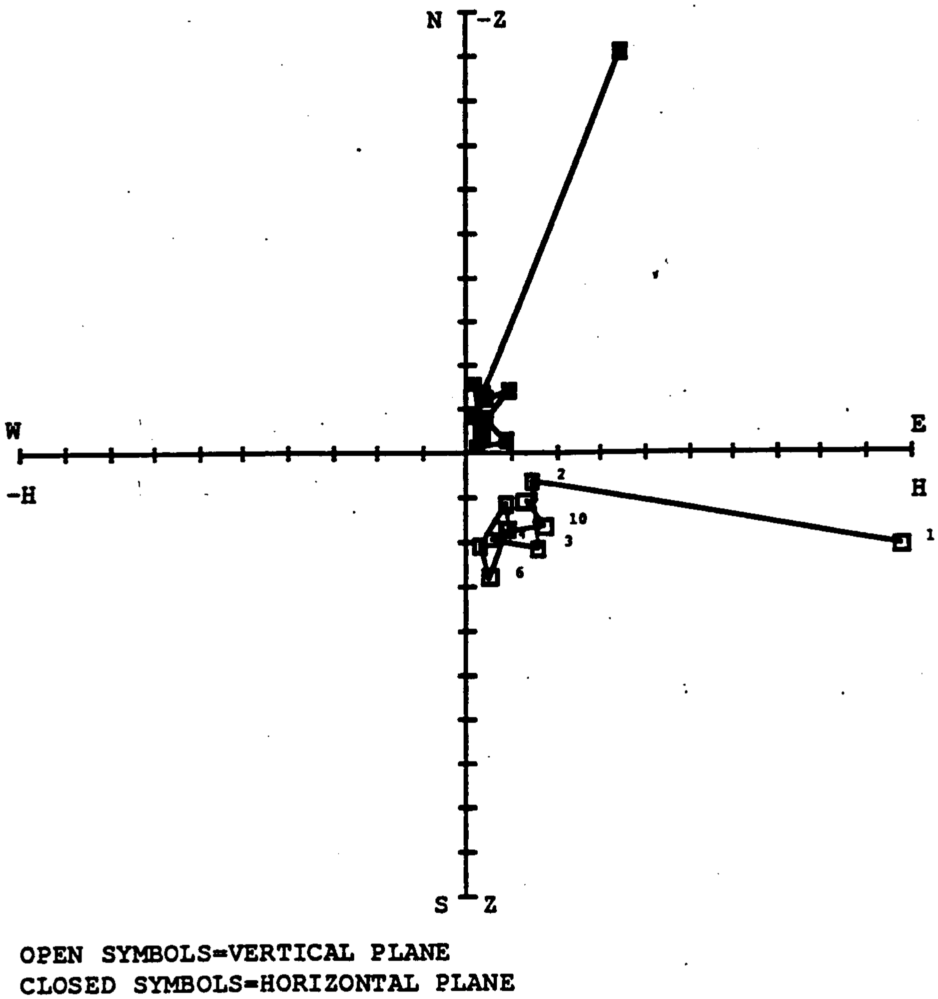


F6.8A

	STEP	DECL	INCL	mA/m
1	NRM	19.7	20.3	0.00
2	100	10.9	20.7	0.00
3	125	4.0	49.6	0.00
4	150	40.0	78.7	0.00
5	175	13.5	64.8	0.00
6	200	152.1	64.3	0.00
7	225	0.3	76.2	0.00
8	250	129.2	46.7	0.00

OPEN SYMBOLS=VERTICAL PLANE
CLOSED SYMBOLS=HORIZONTAL PLANE

Figure 13. Orthogonal diagram (A-Z plot) showing a rather stable behavior of magnetic remanence during stepwise demagnetization of a hematitic lime wackestone (sample 6.8a) from the upper surface of the Argentine Limestone at section F-1. Characteristic remanent magnetism appears to be normal.



F6.8B

	STEP	DECL	INCL	mA/m
1	NRM	20.7	12.1	0.006
2	100	16.3	25.0	0.000
3	125	5.5	53.4	0.001
4	150	29.1	73.6	0.001
5	175	11.8	63.4	0.001
6	200	38.4	79.3	0.001
7	225	55.0	83.1	0.001
8	250	72.4	52.5	0.000
9	300	29.0	62.0	0.001
10	325	34.1	44.5	0.001
11	350	19.4	39.5	0.001

Figure 14. Orthogonal diagram (A-Z plot) showing a rather unstable behavior of magnetic remanence during stepwise demagnetization of a hematitic lime wackestone (sample 6.8b) from the upper surface of the Argentine Limestone at section F-1. Characteristic remanent magnetism appears to be normal.

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