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MagnetoSusceptibility Event and Cyclostratigraphy (MSEC) of the Eifelian-Givetian GSSP and associated boundary sequences in north Africa and Europe

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Magnetosusceptibility event and cyclostratigraphy (MSEC) is used to define magnetic susceptibility (MS) signatures for the Eifelian-Givetian GSSP in southern Morocco and four other Eifelian-Givetian boundary sequences in Morocco, southern France, and the Czech Republic. MSEC data from the GSSP are used to identify nine first-order isochronous MSEC events for chronocorrelation.

MSEC data clearly define a new abiotic Late Eifelian MSEC Event that immediately precedes the Eifelian-Givetian boundary and encompasses the biotic Kacák and otomari *Events. The MSEC event begins in the upper* Tortodus kockelianus kockelianus *Zone and ends in the upper* Polygnathus ensensis *Zone. This Event occurs in the same stratigraphic position in the boundary sequences studied. The characteristics of the Late Eifelian MSEC Event are those of a prolonged high stand in global sea level.*

Introduction

The boundary for the Eifelian - Givetian Stage Global Stratotype Section and Point (GSSP) was agreed upon by members of the Subcommission on Devonian Stratigraphy (SDS) in Rabat, Morocco, in 1991, and ratified in 1995 by the ICS and IUGS (Walliser et al., 1995). The GSSP was placed in a section at Jebel Mech Irdane in the Tafilalt of the western Sahara of southern Morocco (Figure 1). At the time of the GSSP ratification, the use of magnetic susceptibility (MS) for correlation and comparison in the context of establishing time boundaries had not yet reached maturity (Crick et al., 1994). Subsequent use of MS for purposes of detailed correlation (Crick and Ellwood, 1995; Crick and Ellwood, 1996; Crick et al., 1997a; Crick et al., 1997b) now allows the use of MS data to characterize and establish MSEC data sets for most marine sequences.

MSEC is a type of magnetostratigraphy that is dependent on the induced magnetization of rock instead of the often altered and less reliable remanent magnetization of polarity studies. MSEC data are particularly useful in the identification of events for event-stratigraphy and orbital forcing cycles for cyclostratigraphy (Crick and Ellwood, 1995; Crick and Ellwood, 1996; Crick et al., 1997a; Ellwood et al., 1995; Ellwood et al., 1996; Ellwood et al., 1997). Interregional and other types of long-distance chronocorrelation between MSEC data sets are possible when the lithological variations producing the MS variations are the result of "random" events or regional and global (orbital forced) climate changes (Crick and Ellwood, 1995; Crick and Ellwood, 1996; Crick et al., 1997b). The MSEC signature of a sedimentary sequence records the complexity of sedimentary processes, often driven by climatic/orbital forcing cycles. These cycles produce a rhythmicity in the MSEC data that exhibits an apparent lack of uniqueness. For this reason the utility of the MSEC method is dependent on biostratigraphy for temporal indexing within sequences. With high-density sampling, MSEC data can provide event-stratigraphic chronocorrelations at resolutions exceeding those of the best biostratigraphy.

Although the major Eifelian - Givetian boundary sequences of Morocco and France are represented by only four to six meters of sediment, they are replete with MSEC events. MSEC events allow the use of event stratigraphy as an alternate means of characterizing the boundary sequences, and these events can then be correlated between sections, such as the GSSP to sections with different or less than adequate biozone control. Because MSEC data are largely independent of facies and isochronous, MSEC based event stratigraphy provides chronocorrelation between well zoned pelagic sequences and their coeval non-pelagic counterparts.

Magnetic susceptibility

MS is basically a proxy for the lithogenic or detrital fraction of marine sediment. Roughly, it is a quantitative measure of the amount of iron-bearing minerals in a sample (Ellwood et al., 1988; Ellwood et al., 1996). It is important to note that MS data are very different from the magnetic polarities that record the magnetic properties of Earth's magnetic field in rocks. Like magnetic polarities that depend on the conservation of iron in rocks, MS also depends on the preservation of iron. However, unlike magnetic polarities that can be easily remagnetized by heating, MS is largely unaffected by low to moderate thermal processes.

Because the magnitude of MS varies inversely to the carbonate content of marine sediment as it tracks the lithogenic/biogenic ratio (Ellwood and Ledbetter, 1977), MS has also proven useful as a paleoclimatic indicator (Curry et al., 1995; Robinson, 1993).

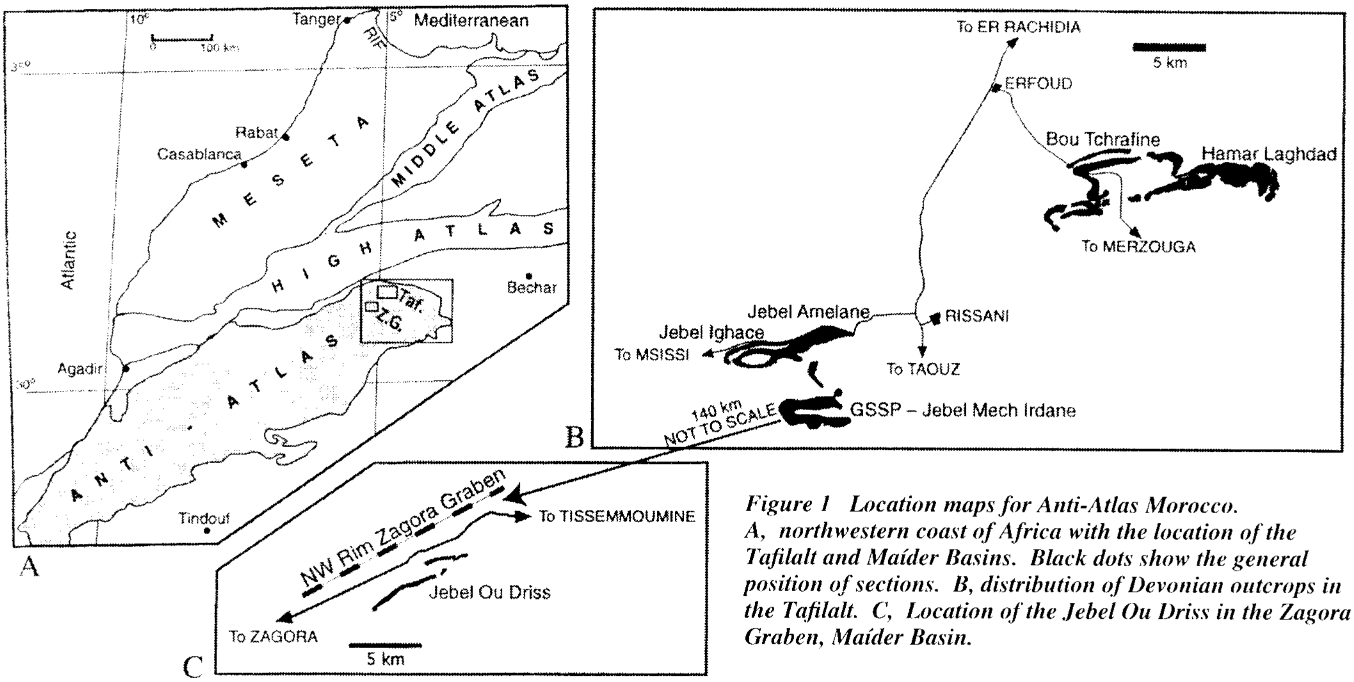

***Figure 1** Location maps for Anti-Atlas Morocco. A, northwestern coast of Africa with the location of the Tafilalt and Maïder Basins. Black dots show the general position of sections. B, distribution of Devonian outcrops in the Tafilalt. C, Location of the Jebel Ou Driss in the Zagora Graben, Maïder Basin.*

Interpretation of MS patterns

In general, variations in MS magnitude within a sequence represent changes in the original rate of supply of the iron-bearing lithogenic or detrital fraction to the marine system. Two, somewhat independent controls, constrain the influx of iron-bearing minerals into the marine realm: the degree of climate-induced erosion, and adjustments in base level either through global sea level rise and fall or through tectonically induced changes in altitude of a region relative to sea level. Climate, controlled by orbital forcing cycles, causes variable erosion rates that, in turn, impart a rhythmicity to sedimentary sequences detectable in MS data and useful for cyclostratigraphy (Crick and Ellwood, 1995; Crick and Ellwood, 1996; Crick et al., 1997a).

Variations in sea level may be controlled by orbital forcing cycles but may also have a random element related to large-scale tectonic controls such as those proposed by Gurnis (1988; 1990). In our experience, random adjustments to base level through relative or net changes in sea level are responsible for the MSEC events reported here. Tectonically induced changes on a global scale will produce first-order isochronous MSEC events that can be identified and correlated on global, regional, and local scales, particularly when sequences are constructed from sediment of the same facies, i.e., pelagic, hemipelagic, neritic. Changes in regional processes will produce second-order MSEC events of moderate frequency and limited in importance to the region of origin. MSEC data will also contain abundant third-order, high-frequency MSEC events produced by local fluctuations in the type and rate of sediment accumulation. Third-order events are generally not replicated among sections. MSEC data will thus exhibit a complex signature that is representative of the processes and controls on the relative iron content of marine sediments. There is, however, an order to this signature. Global events and processes control the basic character of a signature and fix the general position of major peaks and sustained trends observable in MSEC data sets from different paleogeographies. Regional events and processes generally impart a character to the MSEC data that is distinctive within a region but one that does not obscure the global signature. Modifications to the MSEC signature for individual sequences are useful in comparing variations between geographically related sequences and, if unwanted, may be removed by filtering.

The examples used here demonstrate that MSEC event-peaks, shown by comparison with other sections, make exceptionally good chronostratigraphic markers. MSEC events are of two types. Those composed of high magnitudes and those composed of low magnitudes. The high magnitude events are typically of shorter duration and more numerous, whereas, low magnitude events are typically of longer duration and less numerous. Because they represent less time and occur with higher frequency, high magnitude events are more useful for chronocorrelation. The MSEC method must be used in combination with standard methods of biostratigraphy to establish initial biozone boundaries. MSEC can then be used to define chronostratigraphic boundaries as is done with polarity magnetostratigraphic markers under Section 2.4 of the revised guidelines for establishing global chronostratigraphic standards (Remane et al., 1997).

We interpret MSEC events in the following ways. Increases in MS magnitude correspond to relative or net drops in sea level. Highest magnitudes represent maximum *low stands* in sea level. Decreasing magnitudes correspond to relative or net rises in sea level. Lowest magnitudes represent maximum *high stands* in sea level. Increasing magnitudes correspond to relative or net falls in sea level. Commonly a number of consecutive MS lows or highs will coalesce into broad episodes indicative of sea level stasis. The character of the increase or decrease in MS magnitudes within a signature represents the rate of the process or processes responsible for the change.

The Eifelian-Givetian boundary sequence

The conodont definition of the Eifelian - Givetian boundary is based on the entry of a definitive form of the conodont species *Polygnathus hemiansatus* which first appears in Bed 123 of the GSSP boundary sequence at Jebel Mech Irdane (Figures 1B & 3). Representatives of the ammonoid genus *Maenioceras* first occur in the upper part of Bed 119 in association with representatives of other ammonoid groups known to be common in the Givetian. Thus the base of the *Maenioceras* Stufe, widely accepted as the base of the Givetian before the GSSP was established, is now some 0.15 m below the Eifelian - Givetian boundary at the GSSP. The boundary sequence

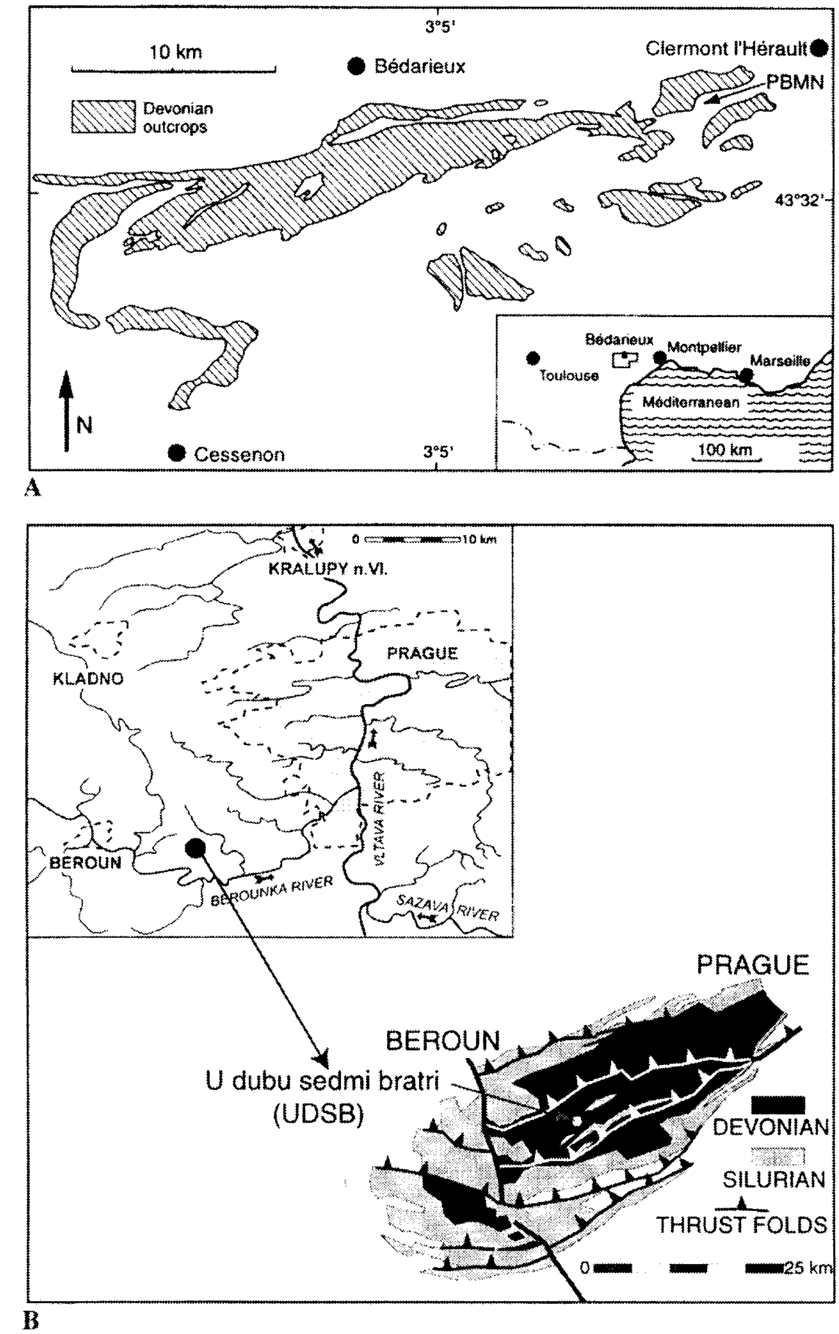

Figure 2 Location maps for southern France and Czech Republic. A, Montagne Noire region and Pic de Bissous area with location of Marbrière Nord (PBMN) section. B, location of U dubu sedmi bratri section (UDSB) in the Prague Basin.

is composed of 45 beds, 22 beds, equivalent to 2.7 m of section, occur below the boundary and 23 beds, equivalent to 2.1 m, occur above the boundary. The boundary sequence consists mostly of pelagic to hemipelagic limestones (some platy or nodular) with the exception of 0.1 m of black shale (Bed 117) that corresponds to the beginning of the *Po. ensensis* zone and the level of the *otomari* Event (Walliser, 1991; Walliser et al., 1995). House (Walliser et al., 1995) refers the whole of the interval, Beds 117 through 119, to the Kacák Event. In this and other sections, but certainly not all, this change from limestone to shale facies, marks the disappearance of *Tortodus kockelianus kockelianus* and the appearance of *Po. ensensis*.

The Kacák - *otomari* Event

The Kacák-*otomari* Event (=*rouvillei* Event of Walliser, 1983) is important for two reasons. First, the event has been used as an alternate marker for the Eifelian-Givetian boundary in neritic sequences and in sequences with poor biostratigraphic control. Second, the conditions imposed by controls on the Kacák-*otomari* Event are thought to have acted as an evolutionary filter to produce the changes used to define the various biozones chosen to define the GSSP (Boucot, 1990; Chlupac and Kukal, 1986; Walliser, 1995). There is some dissatisfaction and confusion with the definition and use of the interval assigned to the Kacák-*otomari* Event (House, 1985; Truyols-Massoni et al., 1985; Walliser, 1995). Much of this can be attributed to differences in the ranges of various fossil groups used to locate the event and to whether the event is viewed as primarily abiotic or biotic. It is both, of course, because changes in faunal makeup did occur in the interval preceding the Eifelian-Givetian boundary. But of equal if not greater importance is evidence of the abiotic event.

The original definition restricted the *otomari* Event to the onset of a black shale interval which also corresponds to the base of the *Nowakia otomari* tentaculite Zone, to the base of the *Cabrieroceras crispiforme* = *rouvillei* goniatite Zone, and to the boundary between *T. k. kockelianus* and *Po. ensensis* Zones (Walliser, 1983). House (1985), on the other hand, considered the whole of the black shale horizon as the event and named it the Kacák Event after the Kacák Member of the Srbsko Formation in Bohemia (for a detailed discussion of the Kacák Member see Chlupac and Kukal, 1986; House, 1985). It is important to note that this black shale interval is not present in all Eifelian-Givetian boundary sequences. Walliser (1995) attempted to clarify the distinction between the *otomari* and the Kacák Events by recognizing two extinction events within the Kacák Event, an earlier one marked by the disappearance of *T. k. kockelianus* and a later one at the Eifelian-Givetian boundary marked by the disappearance of *Po. ensensis*. Walliser suggested that the *otomari* Event, marking the disappearance of *T. k. kockelianus*, retain its original restricted definition and renamed it the Lower Kacák Event. The later extinction event was given the name Upper Kacák Event. It is clear from comparison of definitions of the Kacák -*otomari* Event, that there is little agreement on the timing of the beginning and ending of the event. Suggestions that place the earliest evidence of the event at the disappearance of the goniatite *Pinacites* start the event a bit too early (Truyols-Massoni et al., 1985) and others that place it at the disappearance of *T. k. kockelianus* start the event too late. This is the case because, until now, evidence of the position and duration of the abiotic event responsible for the biotic Kacák and *otomari* Events has been missing.

The data presented here document an abiotic, low-magnitude MSEC event that encompasses the Kacák-*otomari* Event. The boundaries of this MSEC event do not correspond to any known faunal turnover. The lower boundary occurs in the upper *kockelianus* Zone and the upper boundary lies in the upper *Po. ensensis* Zone. The general character of the event is one of an episode of rapid and prolonged rise in sea level. Because of the many differences between the MSEC event and the Kacák - *otomari* Event, we use the term Late Eifelian MSEC Event when referring to the longer interval defined by MS data (Figure 3, Peak 2).

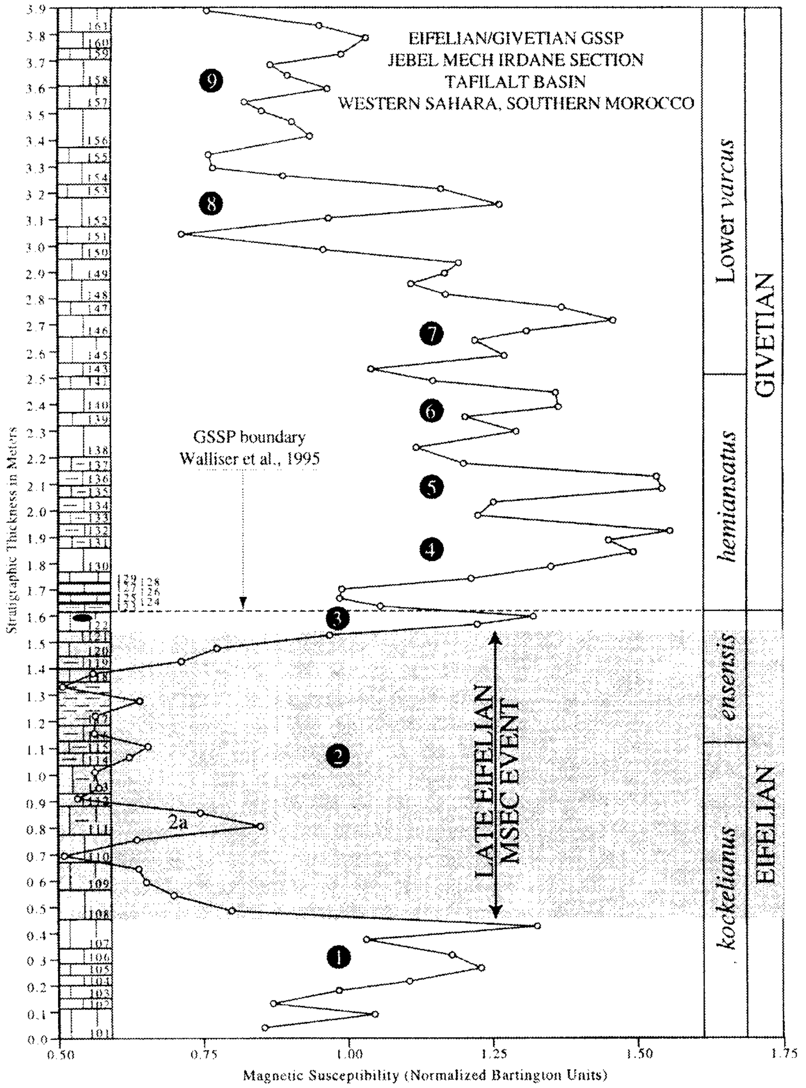

Figure 3 MSEC signature for the Eifelian - Givetian GSSP at Jebel Mech Irdane, Tafilalt, southern Morocco. Bed numbers 101-140 and conodont zonation from Walliser et al. (1995). Numbers on black circles define major MSEC peaks in this and following figures.

MSEC patterns

Tafilalt, southern Morocco

Three sections in the Tafilalt region of the eastern Anti-Atlas of southern Morocco are used for comparison of local sequences (Figure 1). The sequences were originally deposited on the Devonian Tafilalt Platform (Belka et al., 1997). The sections can be located on the 1:100,000 Carte du Maroc, Feuille NH-30-XX-2, Erfoud. The Eifelian - Givetian GSSP is located at Jebel Mech Irdane (JMI) and its lithologic and faunal characteristics have been described in detail (Walliser, 1991; Walliser et al., 1995). The Jebel Amelane (JA) sequence is located 5 km north of the GSSP. The characteristics of its lithology and ammonoid zonation are well known (Becker and House, 1994), but a conodont zonation has not been established for the section. Bou Tchrafine (BT) with a well known and complete succession from Emsian to Upper Famennian is located approximately 20 km northeast of the GSSP. Bou Tchrafine was considered for the Eifelian - Givetian GSSP and its lithologic and faunal characteristics are very well documented (Becker and House, 1994; Bultynck, 1985; Bultynck, 1987; Bultynck, 1989; Bultynck and Hollard, 1980; Bultynck and Walliser, 1990; House and Chlupac, 1987; Walliser, 1991).

Jebel Mech Irdane: The published sequence for the GSSP (Walliser et al., 1995) includes Beds 101 through 145. We have extended the sequence through Bed 161 (Figure 3). The MSEC signature begins with stepped increases in MS magnitude for Beds 101-107 (Peak 1). The first sample in Bed 108, with a magnitude lower than previous values, begins a trend of decreasing MS. There are no obvious differences between the limestones of Beds 107 and those of Beds 108-110. Low MS values continue through Bed 121. The sequence of low magnitudes of Beds 108-121 defines the Late Eifelian MSEC Event. The important reversal in this trend is Peak 2a that begins to develop in the upper portion of Bed 110 and continues through Bed 111. The appearance of *Po. ensensis* coincides with the small peak in Bed 115. The return to low MS values, similar to those of Beds 101-107, begins with Beds 120/121, but before the disappearance of *Po. ensensis*.

The trend of increasing MS magnitudes that defines the upper boundary of the Late Eifelian MSEC Event culminates in Peak 3 in the upper portion of Bed 122, immediately below the GSSP. Peak 3 is followed by another decrease in magnitude, at the point where *Po. hemiansatus* appears, and one that is sustained through Bed 127. A sustained and well-documented increase in MS magnitude follows this low point and begins an interval of enhanced magnitudes through Beds 128-149. The appearance of *Polygnathus varcus* occurs in this interval, which is divisible into Peaks 4, 5, 6, and 7. Magnitudes in Beds 150-161 document a return to values similar to those of the pre-Late Eifelian MSEC Event. Peaks 8 and 9 occur within this interval.

The overall interpretation of the MSEC signature for the sequence is that of a steady lowering of sea level in the middle *T. k. kockelianus* Zone (Peak 1) abruptly reversed to a sustained high stand through the remainder of the *T. k. kockelianus* Zone and all but the latest *Po. ensensis* Zone (Peak 2). Sea level begins to decrease in the latest *Po. ensensis* Zone and, although variable, an interval of low sea level stand continues through the *Po. hemiansatus* Zone and into the Lower *Po. varcus* Zone (Peaks 3-7). A shift toward an increase in sea level occurs in the early portion of the Lower *Po. varcus* Zone and continues to the end of the sequence (Peaks 8-9). This interpretation is supported by comparison with the T-R Cycles of Johnson et al. (1985). Although the T-R Cycles of Johnson et al. (1985) have not been formerly recognized in north Africa, interpretation of the MSEC data in the context of sea level curves shows a rough correspondence with transgressive peaks occurring consistently earlier in southern Morocco than in North America. The latest portion (shallowing) of T-R Cycle Ie is essentially equivalent to the sequence prior to the Late Eifelian MSEC Event (Beds 101-107). The deepening episode marking the Late Eifelian MSEC Event corresponds to the earlier portion of T-R Cycle If. It is likely that the shallowing event following the Eifelian - Givetian boundary corresponds to the completion of the first subcycle of Cycle If.

Jebel Amelane: The JA sequence (Figure 4) is lithologically different from the GSSP but the MSEC signature is basically the same for the boundary sequence, with few variations. Differences are related to either changes in rates of sediment accumulation, that modify the spacing of peaks, or to relative differences in magnitudes. Differences in section thickness indicate that the rate of sediment accumulation at JA was 30% greater than at the GSSP. GSSP peaks 1-9 are present at JA, although magnitudes of JA Peaks 1 and 3 are less than those of the GSSP, Peak 2 is the same, and Peak 9 magni-

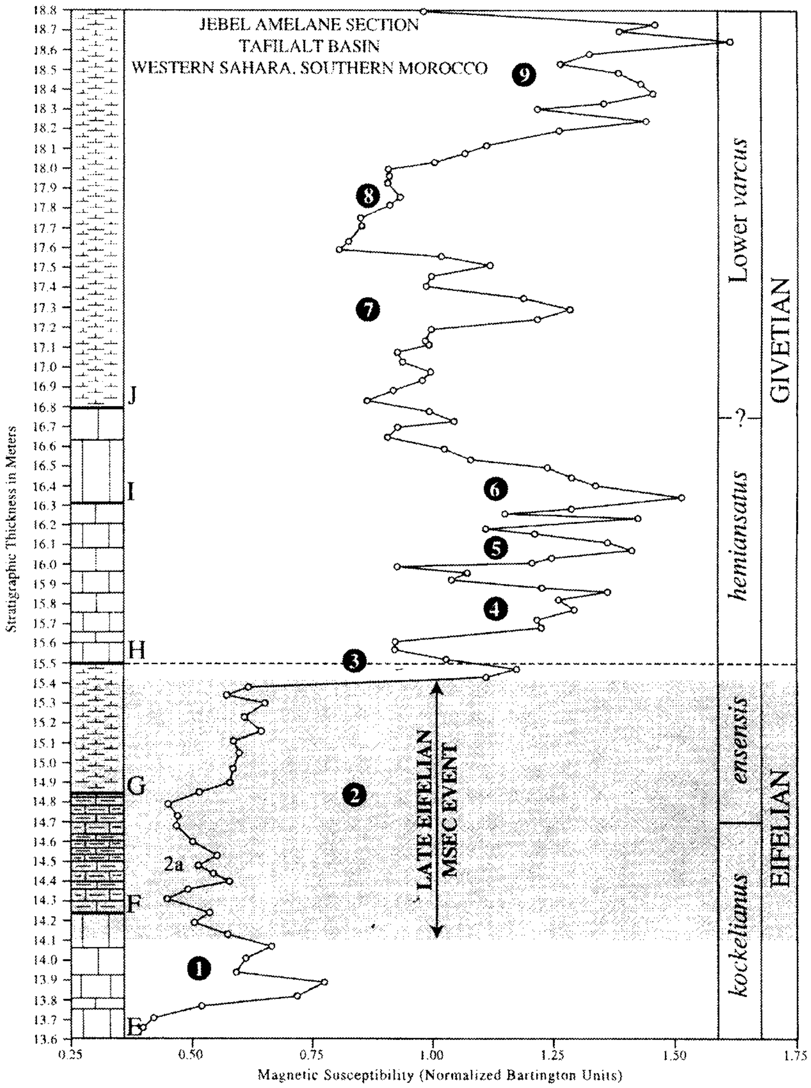

Figure 4 MSEC signature for the Eifelian - Givetian boundary sequence at Jebel Amelane (JA), Tafilalt, southern Morocco. The conodont zonation is adapted from the Bou Tchrafine section (see text for details).

tude is greater. The boundaries of the Late Eifelian MSEC Event (Peak 2) are well defined and in the same biostratigraphic positions relative to GSSP Peaks 1 and 3.

The conodont zonation for *T. k. kockelianus*, *Po. ensensis*, and *Po. hemiansatus* for this sequence (Figure 4) was extrapolated from the position of key ammonoids in sections where both ammonoid and conodont zonations have been established (Bou Tchrafine is an example). This was not possible for the base of the *Po. varcus* Zone and the base of this zone was placed relative to GSSP Peak 6 (Figure 3).

Bou Tchrafine: The BT sequence (Figure 5) is also lithologically different from the GSSP but the MSEC signature is similar to both the GSSP and JA for the boundary sequence, with only a few variations. Like at JA, differences are related to either changes in rates of sediment accumulation, affecting the spacing of peaks, or to relative differences in magnitudes. The rate of sediment accumulation for BT is roughly the same as for the GSSP over the same interval. GSSP Peaks 1-9 are recognizable, although magnitudes for BT Peaks 1, 8 and 9 are less than those of the GSSP while the magnitude of Peak 2 is greater. The boundaries for the Late Eifelian MSEC Event occur in the same positions relative to GSSP Peaks 1 and 3. The position for the base of the *Po. varcus* Zone was placed relative to GSSP Peak 6 (Figure 3). Bultynck (1987) placed the first occurrence of *Po. varcus* higher in Bed 23. This discrepancy will need to be resolved with additional field collections.

Ma'der, southern Morocco

For regional and inter-basin comparison we have included the MSEC signature for the Eifelian - Givetian boundary sequence at Jebel Ou Driss (Figure 1C) located in the Zagora Graben, an outlier of the Ma'der Platform (Belka t al., 1997), 55 km northeast of Zagora (1:100,000 Carte du Maroc, Feuille NH-30-XIII-4, Tarhbalt). The Ma'der is located southwest of the Tafilalt and Ou Driss is approximately 140 km southwest of Mech Irdane. The data reported here come from the Ou Driss est (ODE) section of Hollard and Jacquemont (1956) and Bultynck (1989). Details of stratigraphy and biostratigraphy are given in Hollard (1974) and Bultynck (1987, 1989).

Jebel Ou Driss est: The ODE sequence (Figure 6) has a much larger neritic component than the Tafilalt sequences, and the rate of sediment accumulation for the ODE boundary sequence is six times that of the GSSP. The MSEC data set for ODE was based on material from biostratigraphic samples of wider and more variable spacing than those of other sections, and the resolution is correspondingly lower for the ODE sequence. The ODE signature begins early enough in the *T. k. kockelianus* Zone to record GSSP Peak 2a in the Late Eifelian MSEC Event, and continues through the Eifelian - Givetian boundary (GSSP Peak 3) and GSSP Peak 4 in the lower portion of the *Po. hemiansatus* Zone. We have tentatively placed the base of the Late Eifelian MSEC Event relative to its position to Peak 2a. The larger neritic component of ODE is responsible for the greater MS magnitudes observed for the sequence.

Montagne Noire, southern France

The well known Eifelian - Givetian boundary sequence of the Marbrière Nord sequence (PBMN) on the northern slope of Pic de Bissous in the southeastern Montagne Noire, Languedoc Province (Figure 2A), was chosen for extra-regional comparison (Figure 7). The Marbrière Nord quarry is located on the 1:25,000 Lodève sheet, 2643 ouest. Detailed descriptions of the sequence can be found in Feist (1990) and Walliser (1990).

Marbrière Nord - Pic de Bissous: The boundary sequence at PBMN consists of beds of a pelagic to hemipelagic origin deposited in a basinal environment during the period when the region was part of the northern margin of Gondwana (Galle et al., 1995). The rate of sediment accumulation for this portion of the PBMN section was approximately 60% greater than the GSSP.

The PBMN MSEC signature is much the same as that of the GSSP. All GSSP Peaks are present allowing easy correlation between PBMN and the Tafilalt sections. The base of the *Po. varcus* Zone, established by Walliser (1990), occurs at the top of Peak 6 as it does in the GSSP. The character of the MSEC data set differs, however, in three respects. First, high magnitude peaks at PBMN equal or exceed the highest magnitude peaks of Tafilalt sections and Peak 3 magnitude is nearly twice that of any Tafilalt section. This indicates a higher concentration of iron resulting from a greater influx of lithogenic material during periods of low stands of sea level (Peaks 1, 3, 4, 5, 6 & 7). Second, variations in magnitude are subdued above Peak 6, suggesting that sea level fluctuations for the *Po. varcus* Zone were somewhat different from those of the *T. k. kockelianus, Po. ensensis*, and *Po. hemiansatus* Zones. Third, the sustained low stand of sea level of the earliest Givetian observed in the Tafilalt sections and characteristic of the *Po. hemiansatus* Zone in these sections (Peaks 5-7) is not present in the PBMN boundary

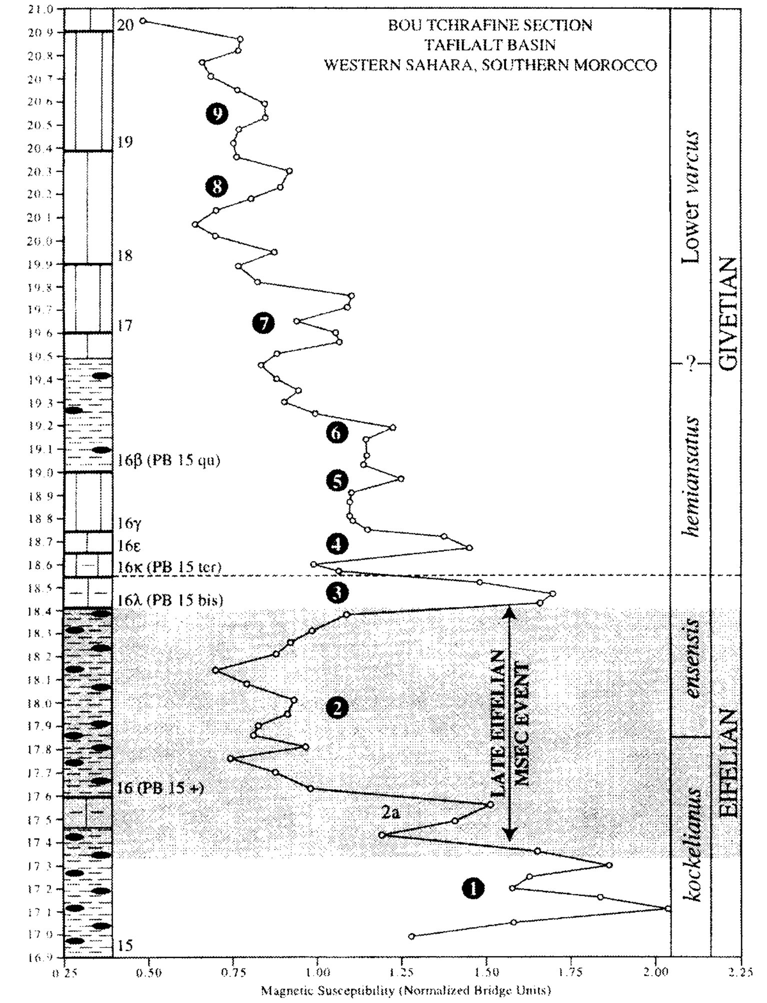

Figure 5 MSEC signature for the Eifelian - Givetian boundary sequence at Bou Tchrafine (BT), Tafilalt, southern Morocco. Bed numbers from Becker and House (1994). Conodont zonation from Bultnyck (1989).

sequence. This indicates a major regional difference between the Tafilalt and Montagne Noire in sea-level stand.

Prague Basin, Czech Republic

The U dubu sedmi bratri sequence (UDSB) (Figure 8), located in the Prague Basin approximately 20 km southwest of the city of Prague (Figure 2B), is also used for extra-regional comparison.

U dubu sedmi bratri: Consisting of basinal facies of limited exposure, the section begins in the Chotec Limestone and ends in the Kacák Shale Member (Figure 8). The biostratigraphy for UDSB is not mature and the conodont zonation used in Figure 8 is only approximate. The Eifelian - Givetian boundary of Figure 8 is based on the carbon and oxygen isotope record for this and other sections established by Hladiková et al. (1997). The UDSB signature begins in the *T. k. kockelianus* Zone above the base of the Late Eifelian MSEC Event and within GSSP Peak 2. Prior to the top of the Chotec, MS magnitudes begin to increase just below the boundary in the latest *Po. ensensis* Zone, forming Peak 3. The sequence then duplicates GSSP Peaks 4 and 5 in the *Po. hemiansatus* Zone.

The most controversial aspect of the UDSB signature is that it places the Late Eifelian MSEC Event in the Chotec Limestone which also places the Kacák Event in the Chotec Limestone rather than the Kacák Shale Member. It should be noted, however, that House (1983) based the definition of the Kacák Event not on a physical event but on the appearance of the ammonoid genus *Maenioceras*. We have already demonstrated with the Tafilalt and Montagne Noire sequences that the Late Eifelian MSEC Event begins well before the Kacák Event. We suggest that this is also the case in the UDSB sequence.

Conclusions

Several conclusions can be drawn concerning the use of MSEC data applied to marine pelagic-hemipelagic sequences:

1. MSEC signatures for the Eifelian - Givetian boundary sequences are thought to be typical of marine pelagic-hemipelagic sediments and are composed of "random" isochronous, and facies-independent MSEC events suitable for chronocorrelation. These events are independent of biotic events, although biotic events may be highly dependent on the controls or processes that created the conditions that produced the MSEC event. MSEC events record relative and net changes in sea level through controls on the delivery of iron-bearing minerals to the marine system, and are thus a proxy for changes in sea level. Nine MSEC events were identified for the Eifelian - Givetian GSSP boundary sequence and used to establish chronocorrelations among boundary sequences from southern Morocco through the Montagne Noire of southern France to the Prague Basin in the Czech Republic.

2. The Late Eifelian MSEC Event is defined by an interval of prolonged low MS values in the Eifelian - Givetian GSSP and is also seen in all other studied sections from southern Morocco, southern France, and the Czech Republic. The Event begins in the upper *T. k. kockelianus* Zone and ends in the late *Po. ensensis* Zone just prior to the Eifelian - Givetian boundary. The Kacák Event and the *otomari* Event are included within the Late Eifelian MSEC Event. The low MS values of the Event are suggestive of a prolonged high-stand in sea level, and the nature of the Event has elements of the Johnson et al. (1985) T-R Cycles Ie and If.

3. The reproducibility of the GSSP MSEC signature in boundary sequences of other Moroccan sections and those of southern France and the Czech Republic demonstrates the worthiness of using MSEC events and MSEC boundaries for chronocorrelation.

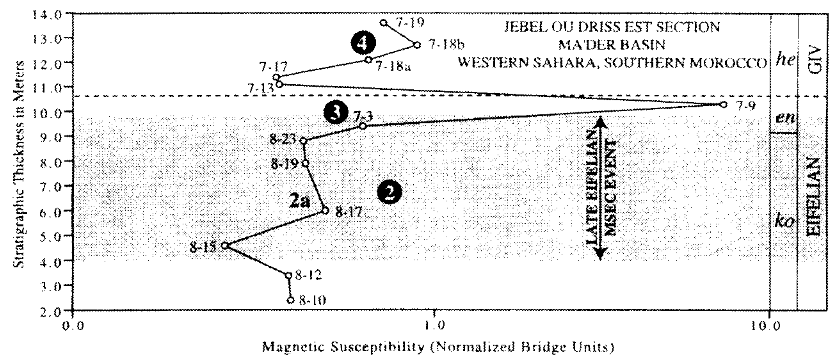

Figure 6 MSEC signature for Eifelian - Givetian boundary sequence at Jebel Ou Driss est (ODE), Ma'der, southern Morocco. Conodont zonation from Bultnyck (1989): ko, **T. k. kockelianus; *en,* Po. ensensis; *he,* Po. hemiansatus.** ***Sample numbers listed in Figure 6 are conodont sample levels of Bultynck (1989). MS magnitudes are an order of magnitude higher than those of Tafilalt sections and logs were used to constrain the abscissa.***

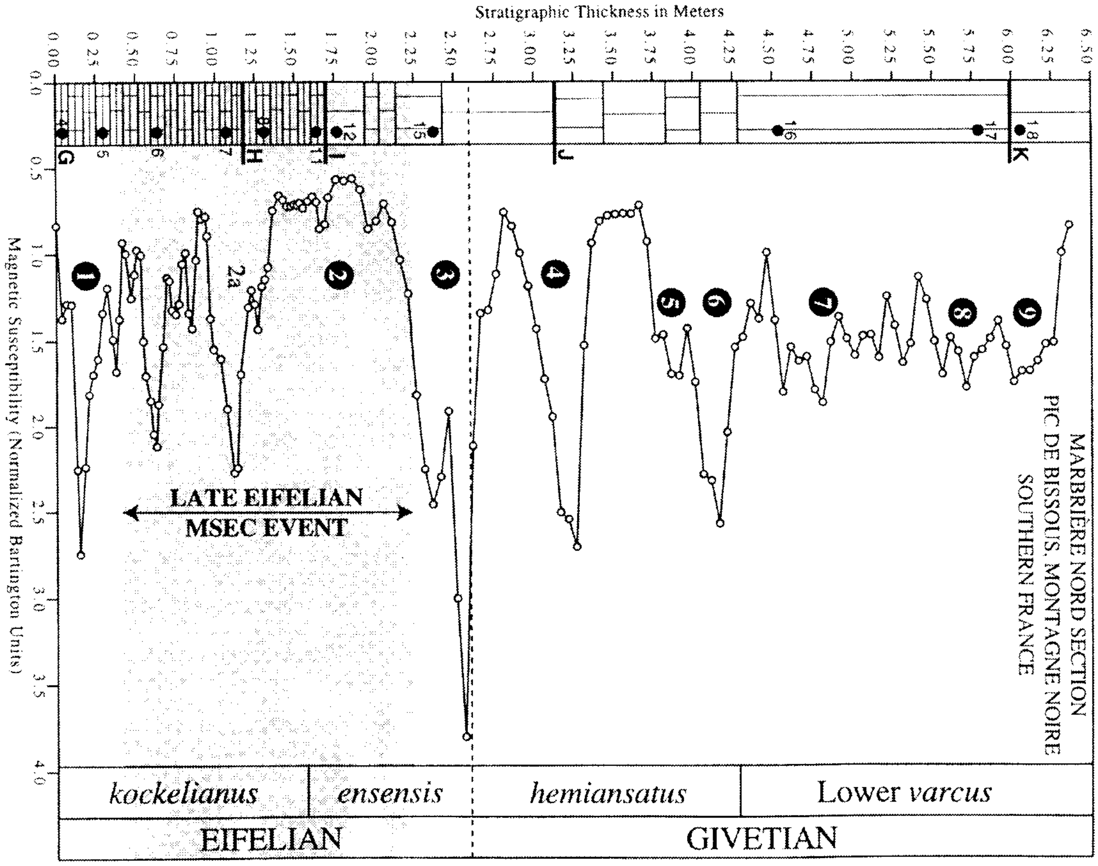

Figure 7 MSEC signature for the Eifelian - Givetian boundary sequence at Marbrière Nord (PBMN) (Montagne Noire, southern France). Sampling interval for Beds G and H was approximately 0.02 m. Sampling interval for remainder of the section was 0.05 m. Bed designations from Feist (1990). Numbered black dots on lithostratigraphic profile are conodont sampling points of Walliser (1990).

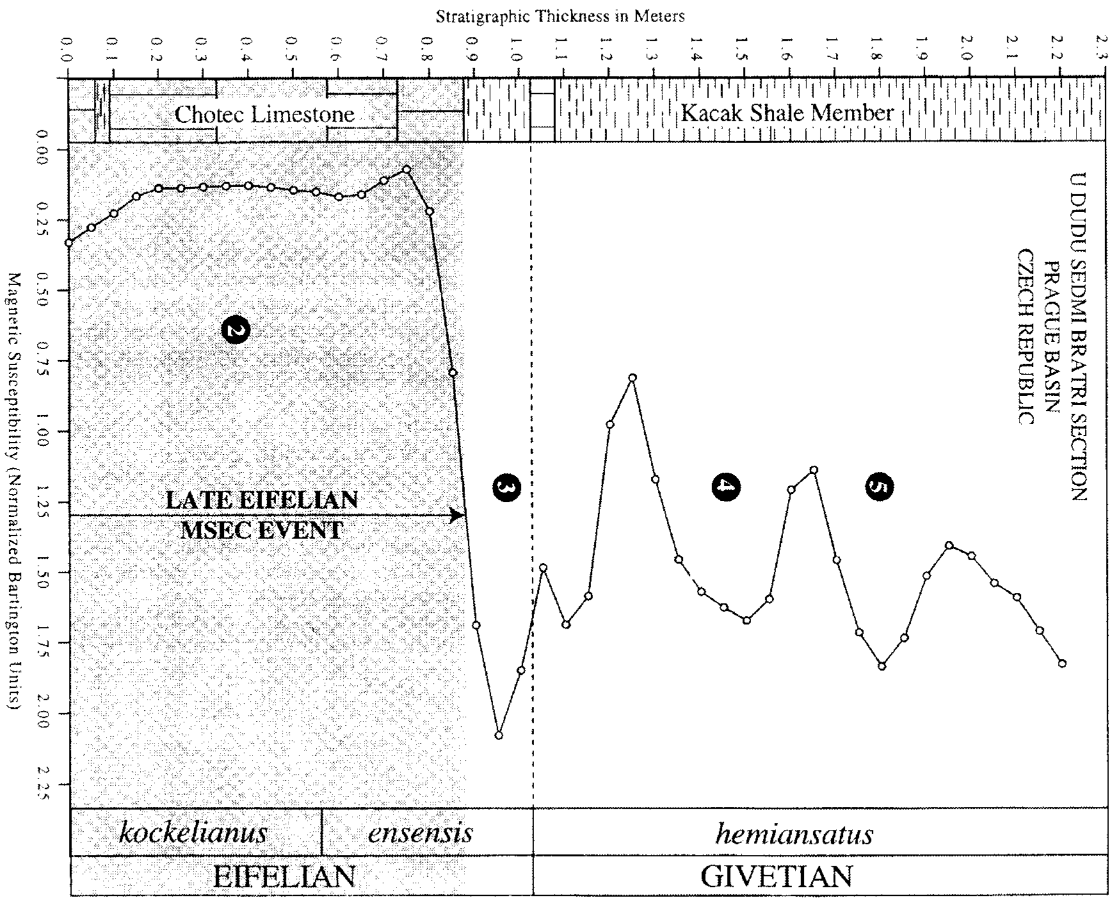

Figure 8 MSEC signature for the Eifelian - Givetian boundary sequence at U dubu sedmi bratri (UDSB), Prague Basin, Czech Republic. The conodont zonation for the interval is approximate only.

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