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Devonian sedimentary microrhythms and a Givetian time scale

MICHAEL R. HOUSE

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A Givetian sequence of pelagic calcilutites of griotte facies in the Montagne Noire shows well developed microrhythmicity at the 56 and 105mm scale. The *rouvillei* and *terebratum* Zones are developed enabling correlation with the international biostratigraphical standard. A correction is made using graphic correlation for a missing portion up to the new upper limit of the Givetian at the base of the Lower *asymmetricus* Zone. This gives an estimate of about 353 cycles at the 56mm scale for the Givetian. Supposing these microrhythms are related to orbital forced climatic changes and using Berger's estimates of duration in the Devonian of the more dominant second precession cycles, calculations are made on the likely duration of the Givetian stage and a time of about 7Ma is favoured. The radiometric estimates of the duration of the Devonian and of the Givetian are extremely uncertain but the 7Ma figure agrees very closely with estimates made by Devonian specialists rather than with the recent Cambridge radiometric scale. Attention is drawn to how these microrhythms, whatever their cause, may enable much greater precision in relative dating of Givetian events using graphic correlation and this is illustrated for the Upper and Lower *pumilio* Events.

M.R. House, Department of Geology, The University, Southampton, SO9 5NH.

Introduction

Perhaps the major problem of sedimentary geology at the present time is the lack of a precise and numerical time scale. This is especially so in the Palaeozoic. It is true we have had in recent years a flood of published times scales, often with supposedly precise figures given of radiometric dates for stage boundaries, but the diverse estimates from publication to publication show that these are spurious. Part of the problem lies in the fact that whilst crude estimates are possible for the boundaries of stratigraphical systems (very crude in the case of the Palaeozoic), theoretical subdivisions of system-level datings are made either on the assumption that stages within the system are of equal duration or supposedly more refined estimates are made on the assumption that the number of faunal zones within a stage gives an estimate of its duration. No biostratigrapher would for one moment support either of these suppositions. Figures resulting from such calculations are almost useless and it is surprising that geophysicists should present such figures as if they were meaningful and that learned publishing houses should print such idle speculation.

The famous American geologist G.K. Gilbert drew attention in 1895 to the wide occurrence of small-scale rhythmicity in the Cretaceous of western USA and suggested a possible causation in climatic oscillations resulting from the documented changes in the orbital patterns of the solar system. Such ideas were developed by Milankovitch (1920, 1941) in relation to possible causes for the Pleistocene glaciation periods. The main oscillations today fall between 19 and 400 000 years and these are referred to as the Milankovitch Band frequencies. It has been shown using isotope analysis of ocean cores that temperature changes during the late Tertiary can be resolved into oscillations reflecting these Milankovitch Band frequencies (Hays *et al.* 1976; Imbrie and Imbrie 1979; Berger *et al.* 1984; Fischer 1986). This paper explores the possibility that certain microrhythms in Givetian pelagic micrites might result from such orbital forcing and reviews numerical calculations which result form this. Essentially it explores ideas expressed elsewhere (House 1985).

Duration of the Devonian

There has been a succession of estimates for the duration of the Devonian using radiometric criteria. Some recent examples of these are shown below:

Author	*Duration in Ma*
Odin 1982	40
Gale and Beckinsale 1983	42
Odin 1985	40
McKerrow *et al.* 1985	58
Snelling 1985	50
Harland *et al.* 1989	46
Cowie and Bassett 1989	55
Menning 1989	46

An average of these figures gives 47.1Ma for the length of the Devonian. But the list also serves to illustrate the considerable imprecision in radiometric dating for the Middle Palaeozoic, since the basic data are reasonably limited and the figures represent subjective nuances of interpretation from author to author.

Duration of the Givetian

Further problems arise when attempts are made to give dates for the stages of the Devonian. Early attempts tried to assess thicknesses accumulated for each stage (Friend and House 1964). More recently, either it has been assumed that stages are of equal duration (Harland *et al.* 1982), or that the number of zones within a stage gives an estimate of the relative lengths of stages. This presumably is based on an assumption that evolutionary rate of change has some constancy. Estimates using this criteria include the recent Cambridge time scale (Harland *et al.* 1989). Yet another approach was adopted by Boucot (1975) who asked Anglo-American specialists on the Devonian to give their impression numerically of the length of stages, and Ziegler (1978) produced a modification of this giving estimates by continental specialists.

Estimates of the percentage of Devonian time represented by the Givetian from these sources are given below. The figure against Boucot (1975) is the average of the six specialists (Boucot, Dutro, House, Klapper, Oliver and Ormiston) whom he asked to estimate Silurian and Devonian stage duration.

Boucot 1975	15.4%
Ziegler 1978	14.9%
Harland *et al.* 1989	7.4%

The Harland *et al.* (1989) estimate is considered to be unacceptably low because they gave a bizarre length for the Lochkovian duration (= Gedinnian) of 26.1%, well over twice any informed estimate, Their Frasnian figure (22.6%) is again well above any other estimate, yet the Frasnian has been reduced in length (both at the top and base) top and base) in recent years by decisions of the Commission on Stratigraphy. An average of the Boucot and Ziegler figures is 15.15% and using the average opinion from radiometric data of the duration of the Devonian given above, this gives an estimted period for the Givetian of 7.1Ma.

Pic de Bissous Givetian section

A near complete section of the Givetian is displayed in the old Mabrière on the northern slope of Pic de Bissous (Vissous), 3km north of Cabrières (Sheet 1:25 000, Lodève 2643 ouest, 6824 31452) Languedoc, SW France. It is best approached by a track leaving route D908 at a point marked by a cross on the road opposite. The track soon diverges and the left hand track leads to the Mabrière whilst the right hand fork leads to the spectacular panorama afforded by the Pic itself.

The succession in the Pic de Bissous quarry is inverted and the beds are more or less horizontal with a slightly undulating dip. The bulk of the section is of the Givetian but the uppermost part of the sequence, mostly above a track at the top of the quarry face, is Eifelian. The facies throughout is pink, red and grey calcilutites of nodular limestone (griotte or knollenkalk) facies with argillite flasers. The section falls within the Pic de Bissous Group of Feist (1985).

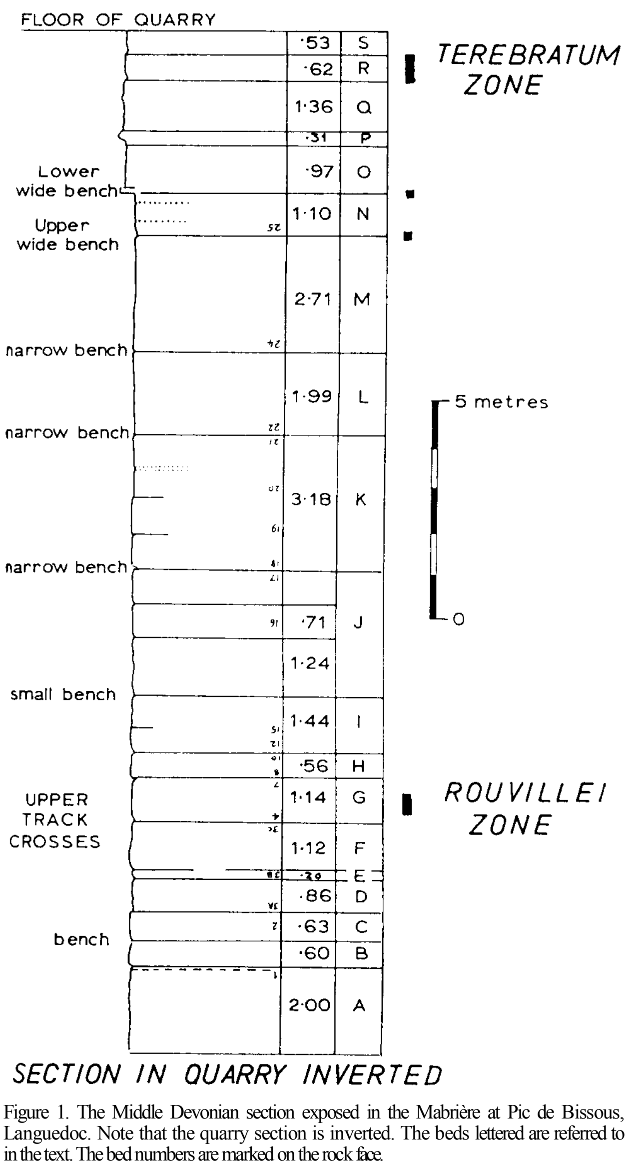

Figure 1. The Middle Devonian section exposed in the Mabrière at Pic de Bissous, Languedoc. Note that the quarry section is inverted. The beds lettered are referred to in the text. The bed numbers are marked on the rock face.

The lowest beds seen in the quarry (Fig. 1) show micrites with *Maenioceras terebratum* of the high Givetian *terebratum* Zone. At a meeting of the Devonian Subcommission in 1983 it was reported that these levels contain conodonts of the Middle *varcus* Zone (Fiest 1983). The fauna is in the uppermost part of Bed R, below Bed S. There is a wide bench at the junction of Beds O and N which shows a shale seam, the surface of which has abundant small brachiopods, crinoid debris and other fossils in grey micrite. A similar seam forming the bench between Beds N and M also shows small fossils and ? *Sobolewia*. Vertical faces in the quarry show cross sections of *Agoniatites* and levels with crinoids and occasional corals and *Cladochonus* (for example at the junction of Beds I and J). Within Bed G, and in the bed numbered 5, a fauna of the Zone of *Cabrieroceras rouvillei* occurs. Goniatiates determined include *Cabr. crispiforme* (Kayser), *Sobolewia sp., Agoniatites costulatus* (d'Archiac and de Verneuil) *and Agoniatites* cf. *vanuxemi* (Hall) (House and Chlupàc 1987).

Throughout the Givetian section the micrites are permeated by small-scale rhythmicity. The rhythmicity shows as corrugations on well-weathered surfaces (Fig. 2A, B, E) and on fresh surfaces the griotte nodular micrites are seen to be interrupted by rather more shaly levels. When some such bedding surfaces are exposed (Fig. 2C) they show branching grooves often filled with argillitic material and have been taken to be trace fossils of some sort, the origin of which is not clear.

It has been possible to measure the width of 107 of the microrhythms and the results are plotted as a histogram (Fig. 3). The microrhythms could not be measured over significant parts of the section either because the surfaces were too fresh to show them or because of inaccessibility. Neverless the whole section shows such small-scale rhythmicity. Averages taken at the top and base of the quarry conform sufficiently to suggest the histogram is approximately typical for the quarry as a whole.

The Subcommission on Devonian Stratigraphy has still to decide on an exact level for the definition of the Eifelian/Givetian boundary, so this is taken for convenience at the base of Bed G. The thickness to the top of the *terebratum* Zone at the top of Bed R is 18.11m. The Subcommission has reached a decision on the top of the Givetian (defined by the base of the Frasnian) and drawn it at the base of the Lower *asymmetricus* Zone. This is higher than the level at the top of the *terebratum* Zone formerly used and means that the uppermost part of the Givetian is not represented in the quarry. It must be exposed in the western vertical face of Pic de Bissous, but that is largely inaccessible and has not been measured. Therefore recourse has been made to Shaw's graphic correlation methods to estimate the missing thickness. The sequence at Bou Tchrafine in the Tafilalt of Morocco has been used for this which similarly has faunas of both *rouvillei* and *terebratum* Zones, but the sequence continues up to the Lower *asymmetricus* Zone, which adds about 1.18m at Bou Tchrafine or about 9.6% of the thickness. This is taken to be the percentage which should be added to the Pic de Bissous section to equate with the Givetian as currently defined which gives 19.85m as the corrected figure. The graphic correlation is shown on Fig. 4. A plot is also made of the Upper and Lower *pumilio* Beds at Bou Tchrafine against the prominent shale seams (and benches) at the base of Beds O and N in the quarry. It is interesting that they approximately correspond and it will be interesting to see if this is substantiated by other methods. Dr E. Schindler, in discussion, has correctly commented that the lithologies are not comparable with typical *pumilio* Bed lithologies, but that is not required if these are a deeper water equivalent.

Interpretation

The pelagic facies represented at the Pic de Bissous is remarkably homogeneous from the Eifelian into the Frasnian. The early Frasnian can be studied on the east side of the Pic. It is unusual in showing the Givetian in a continuous section and with little change in lithology. Rather deep water environments are suggested and

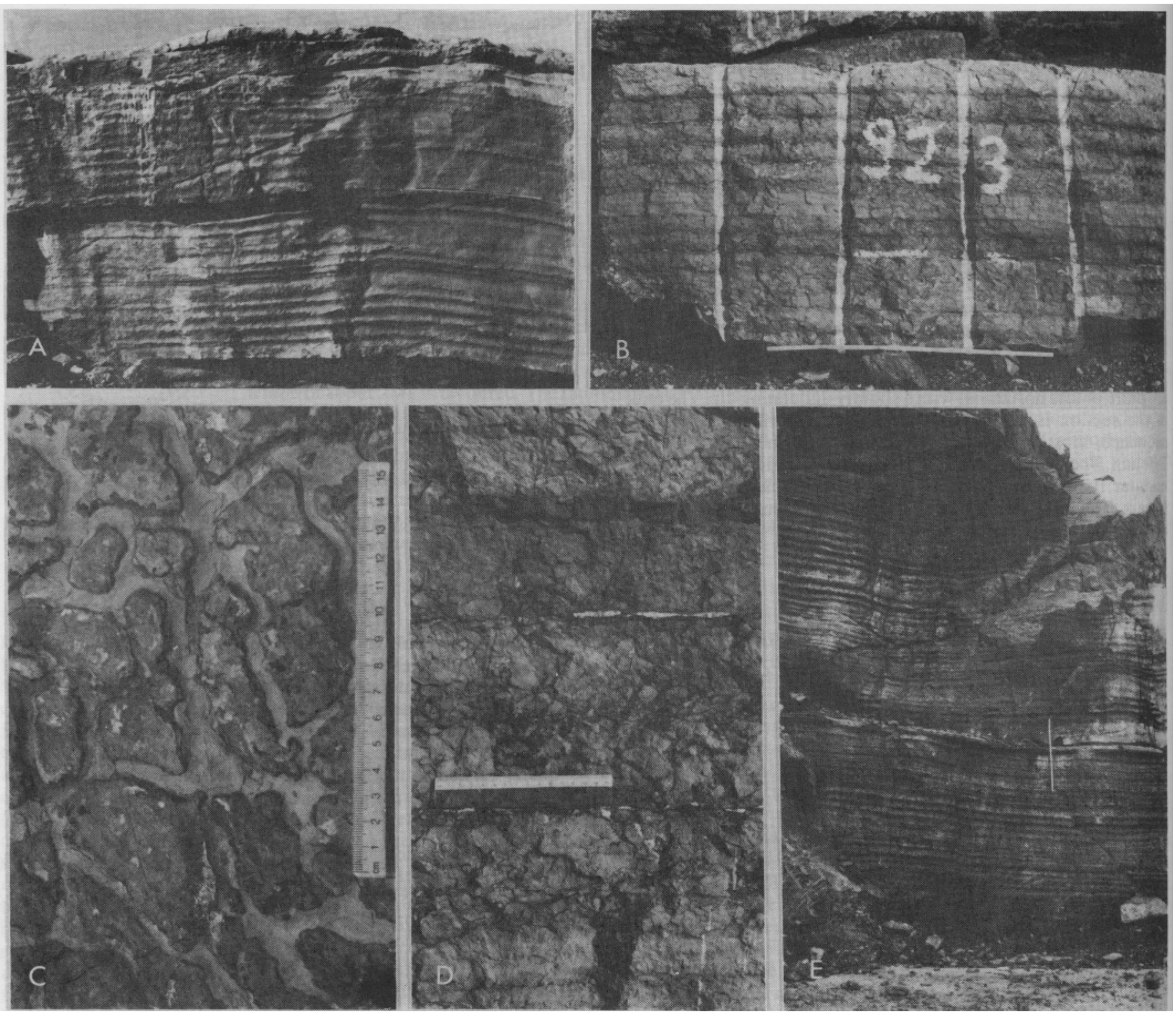

Figure 2. Photographs illustrating the microrhythmicity of the Devonian micrites in the Pic de Bissous quarry. A) The upper part of the sequence at the base of the quarry. Bed R is below the lowest shadow. Bed Q is the unit up to the metre scale resting on a bedding surface. Beds P and O continue to the top and the upper surface of Bed O forms the lower wide bench of the quarry. B,D) A loose quarried block showing the fine-scale rhythmicity with an enlargement of part of it with a 15cm scale. C) The surface of a microrhythm from the upper part of the quarry (oldest) showing the grooving of uncertain origin. E) Microrhythmicity in the lower part of the vertical face of the quarry commencing with the upper wide bench at the base (with Bed N below). Bed M extends up to the narrow bench straddled by the metre scale with Bed L continuing up the vertical and inaccessible face behind.

there is no trace of non-sequences or breaks in sedimentation although the microrhythms show there was a fluctuating pattern throughout.

It will be noticed that the histogram of the microrhythms (Fig. 3) is bimodal, and the second peak is about twice the first, giving average thickness of each as about 56 and 105 respectively. This couplet pattern is common-place in successions thought to be subject to climatic fluctuations which might be orbitally forced (Hart 1987; Weedon 1989; papers in Berger *et al.* 1984). If thickness is approximately proportional to time then the two peaks could represent the interpenetration of two such cycles as those of Precession and those of Obliquity. Both of these today show double oscillations. Berger *et al.* (1989a,b) have shown that these orbital cycles differ in the geological past because they will have been modified by changes in the rate of spin of the earth and changes in the moon's rotation rate around the earth: there is palaeontological evidence to give figures for each in the past. Using these data Berger *et al.* (1989a,b) have given corrected figures for the Precession and Obliquity periods at 380Ma which approximately corresponds to the mid-Devonian and which is used for the calculations here. The Berger *et al.* figures for the mid-Devonian are as follows:

Cycle	*Present Day*	*Mid-Devonian*
Precession (1)	19.0Ka	16.8Ka
(2)	23.0Ka	19.9Ka
Obliquity (1)	41.0Ka	32.1Ka
(2)	54.0Ka	39.5Ka

If the Pic de Bissous microcycles represent the result of the climatic forcing due to these orbital oscillations then the two peaks of the histogram (Fig. 3) may correspond to the Precession and Obliquity cycles the heterodyning of which would produce muting of the higher frequency cycle from time to time. Supposing the 56mm microrhythms continue throughout the succession would give a total of 329 microrhythms for the Givetian in the Pic de Bissous Quarry to which should be added 9.6% for the missing topmost part. This gives a rough total of 353 microcycles at the 56mm level for the Givetian as a whole.

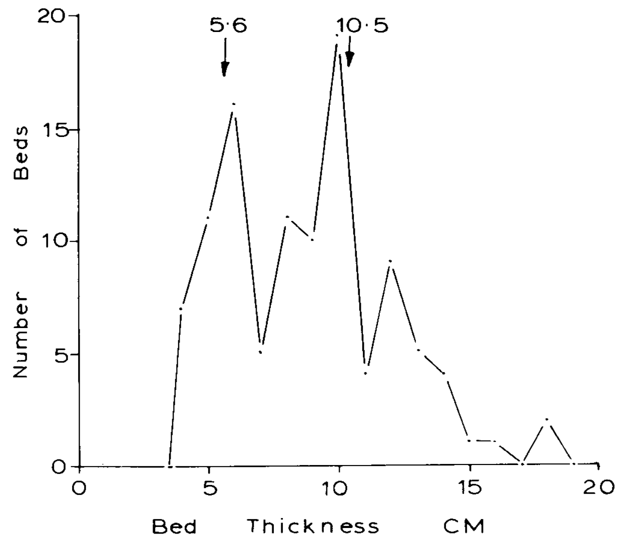

Figure 3. Histogram plotting the thickness of 107 microrhythms in the Pic de Bissous Quarry with approximate averages for the two peaks shown.

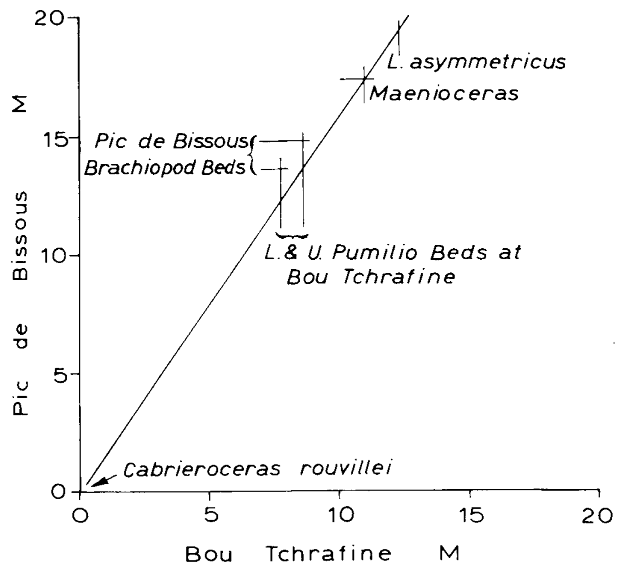

Figure 4. Graphic correlation between the Givetian section at Bou Tchrafine, Erfoud, Morocco, against the section at Pic de Bissous. Levels of the *pumilio* Beds at Bou Tchrafine are shown and the section continues up into the topmost Givetian.

If the first Precession cycle is dominating this would give a Givetian duration of 59Ma. But if the second Precession cycle is dominating, as is usual today, this would give a period of 7.0Ma. The precession cycles today dominate in low latitudes as would have been so for the Montagne Noire Devonian. The Obliquity cycles would have a role in explaining the 106mm microrhthmicity.

Conclusion

On the presumption that the 56mm microrhythmicity so well developed in Pic de Bissous quaff y is caused by the second Precession cycle an estimate is given for the duration of the Givetian of 7.0Ma. An estimate using an average of various radiometric estimates for the duration of the Devonian (ranging from 40 to 58Ma) and specialist estimates of the relative duration of the Givetian stage (15.15%) gives an estimated duration for the length of the Givetian of 7.1Ma. The surprising agreement of these figures suggests that the microrhythmicity results from climatic oscillations resulting upon global insolation changes produced by orbitally forced changes. Orbitally forced rhythmic signatures may prove to be a more accurate method of elucidating time in the past than any now being employed.

Attention is drawn to how homogeneous and complete sections such as that at Pic de Bissous may provide a standard of reference for Givetian time using graphic correlation in addition to the time scale provided by the microrhythmicity.

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References

Berger, A., Imbrie, J., Hays, G., Kukla, G. and Satzmanm, B. (eds) 1984. *Milankovitch and Climate.* Reidel, Dordrecht, 895 pp.

Berger, A., Loutre, M.F. and Dehant, V. 1989a. Influence of the changing lunar orbit on the astronomical frequencies of Pre-Quaternary insolation patterns. *Paleoceanography, 4,* 555-564.

Berger, A., Loutre, M.F. and Dehant, V. 1989b. Pre-Quaternary Milankovitch frequencies. *Nature, London, 342,* 133.

Boucot, A., 1975. Evolution and extinction rate controls. *Developments in Palaeontology and Stratigraphy, 1,* Elsevier, 467 pp.

Cowie, J.W. and Bassett, M.G. 1989. International Union of Geological Sciences, 1989 Global Stratigraphic Chart. *Episodes, 12 (2),* Supplement.

Feist, R. (ed.) 1983. *The Devonian of the Eastern Montagne Noire.* Guidebook, Field Trip, International Subcommission on Devonian Stratigraphy, Montagne Noire, September 1983. Montpellier, 62 pp.

Fiest, R. 1985. Devonian stratigraphy of the South-Eastern Montagne Noire (France). *Courier Forschungsinstitut Senckenberg, 75,* 331-352.

Fischer, A.G. 1986. Climatic rhythms recorded in strata. *Annual Reviews, Earth and Planetary Sciences, 14,* 351-376.

Friend, P.F. and House, M.R. 1964. The Devonian period. *Quarterly Journal of the Geological Society of London, 120S,* 233-236.

Gale, N.H. and Beckinsale, R.D. 1983. Comments on the paper `Fission track dating of Ordovician and Silurian stratotypes' by R.J. Ross and others. *Geological Magazine, 120,* 295-302.

Gilbert, J.K. 1895. Sedimentary measurement of Cretaceous time. *Journal of Geology, 1895,* 121-127.

Harland, W.B., Cox, A.V., Llewellyn, P.G., Pickton, C.A.G., Smith, A.G. and Walters, R. 1982. *Geologic Time Scale.* Cambridge University Press, Cambridge. 131 pp.

Harland, W.B., Armstrong, R.L., Cox, A.V., Craig, L.E., Smith, A.G., and Smith, D.G. 1989. *A Geological Time Scale 1989.* Cambridge University Press, Cambridge, 263 pp.

Hart, M.B. 1989. Orbitally induced cycles in the Chalk Facies of the United Kingdom. *Cretaceous Research, 8,* 335-348.

Hays, J.D., Imbrie, J. and Shackelton, N.J. 1976. Variations in the Earth's orbit: pacemaker of the Ice Ages. *Science, 194,* 1121-1132.

House, M.R. 1985. A new approach to an absolute timescale from measurements of orbital cycles and sedimentary microrhythms, *Nature, London, 316,* 731-725.

House, M.R. and Chlupac, I. 1987. *Goniatite faunas relevant to the definition of the Eifelian/Givetian boundary.* Document submitted to the Subcommission on Devonian Stratigraphy, Calgary, 1987, 14 pp.

Imbrie, J. and Imbrie, J.Z. 1979. *Ice Ages, Solving the Mystery.* Enslow, Short Hills, New Jersey. 224 pp.

McKerrow, W.S., Lambert, R. St J. and Cocks, L.R.M. 1985. The Ordovician, Silurian and Devonian periods. *Geological Society of London, Memoir 10,* 73-80.

Menning, M. 1989. A synopsis of numerical time scales 1917-1986. *Episodes,* 12, 3-5.

Milankovitch, M. 1920. *Théorie Mathématique des Phénomènes Thermiques Produits par la Radiation Solaire.* Académie Yougoslave des Sciences et des Arts de Zagreb, Gauthiers-Villiers, Paris.

Milankovitch, M. 1941. Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitenproblem. *Academie Royale Serrbe, Edition Speciale, 133,* 633 pp.

Odin, G.S. 1985. Remarks on the numerical scale of Ordovician to Devonian times. *Geological Society of London, Memoir 10,* 93-98.

Snelling, N.J. 1985. An interim time-scale. *Geological Society of London, Memoir 10,* 261-265.

Weedon, G.P. 1989. The detection and illustration of regular sedimentary cycles using Walsh power spectra and filtering, with examples from the Lias of Switzerland. *Journal of the Geological Society, London, 146,* 133-144.

Ziegler, W. 1978. Devonian. *In:* Choen, G.V., Glaessner, M.F. and Hedberg, H.D. (eds). *Contributions to the Geological Times-Scale. American Association of Petroleum, Studies in Geology, 6,* 337-339.