The Ordovician Time Scale – New Refinements

By REUBEN J. ROSS JR. and CHARLES W. NAESER

R. J. Ross Jr., Department of Geology, Colorado School of Mines, Golden, Colorado 80401, U.S.A.

C. W. Naeser, U. S. Geological Survey, MS 424, Denver Federal Center, Colorado 80225, U.S.A.

Introduction

Seven fission-track dates and one K/Ar date constitute great progress in isotopic dating of the Ordovician Period since the Ordovician Symposium at Birmingham in 1974. Speaking at Birmingham Professor Frank J. Fitch warned that the few Ordovician dates then available would be in need of constant revision because of inadequate geological interpretation and analytical methods. Fitch *et al.* (1976) charged that there are two approaches to the construction of a time scale. The first is the "direct, strictly scientific approach of stratigraphical geology" which requires that the stratigraphic position of the rocks to be dated be fully documented; ideal are "datable sediments, lavas, tuffs, and bentonites intercalated within richly fossiliferous strata". The derived isotopic data should be "precise and unambiguous". At that time no dates met these requirements and without them there could be no "viable Ordovician time-scale".

The second approach is indirect, subjective, and geologically intuitive. All available age data, both good and bad, are weighed against "total geological background". "Although a very poor alternative" this was the only source of any Ordovician dates in 1975, and the method is still very much in evidence, particularly in interpreting emplacement of ophiolite complexes.

Although the paper by Fitch *et al.* (1976) seemed pessimistic when presented, it clearly divided Ordovician isotopic dates into good and not-so-good categories, for which the score was nil to too many. The paper served as an inspiration for a project that was undertaken shortly thereafter in Wales, Shropshire, and southern Scotland (Ross *et al.* 1982). It may also have inspired the critical dating of the Upper Tremadoc Rhobell Volcanics in north Wales by Kokelaar, Fitch, and Hooker (1982).

Dating Stratotypes and other sections

In the autumn of 1976 fourteen British and North American colleagues took 35 samples of bentonites and tuffs interbedded in the classical sections of each of the Series of the Ordovician and Silurian Systems, except the Tremadoc. The gratifying results of 11 samples were reported in abstract form two years later (Ross *et al.*, 1978) and a complete report including all supporting stratigraphic and chemical evidence has recently been published (Ross *et al.*, 1982), greatly enhanced by the contributions of our British colleagues. The entire effort would have failed had not the British contingent unearthed from countless geologic reports the whereabouts of a great many Ordovician and Silurian bentonites and tuffs, many more than those from which we were able to collect, and had they not guided us to them. Also essential was the financial assistance of the National Geographic Society.

The useable dates are included in Figure 1 and Table A (Ross *et al.*, 1982, Table 1. Kokelar *et al.*, 1982). They do not include a date for the base of the Tremadoc or any way to accurately date the Caradoc-Ashgill boundary. They do include significant dates for the Series of the Ordovician and Silurian, all stratigraphically defined to conform to the first category of Fitch et al. (1976).

The Rhobell Volcanic Group, exposed near Dolgellau in northern Wales, is considered to be uppermost Tremadoc on biostratigraphic

In Bruton, D. L. (ed.), 1984. *Aspects of the Ordovician System.* 5–10. Palaeontological Contributions from the University of Oslo, No. 295, Universitetsforlaget.

grounds and has been dated by the K/Ar method at 508 ± 11 m.y. by Kokelaar *et al.* (1982). This date supports the fission-track dating of the Llyfnant Flags as a minimum age (Figure 1), but not the assignment of 482–484 m.y. dating to the Arenig-Tremadoc boundary by Gale et al. (1980). This Tremadoc date provides an important extension of the Ordovician and with the new Cambrian dates reported below requires that the base of the Ordovician System should be about 515 m.y. in age. The boundary between the Arenig and Tremadoc should probably be dated at 500–505 m.y.

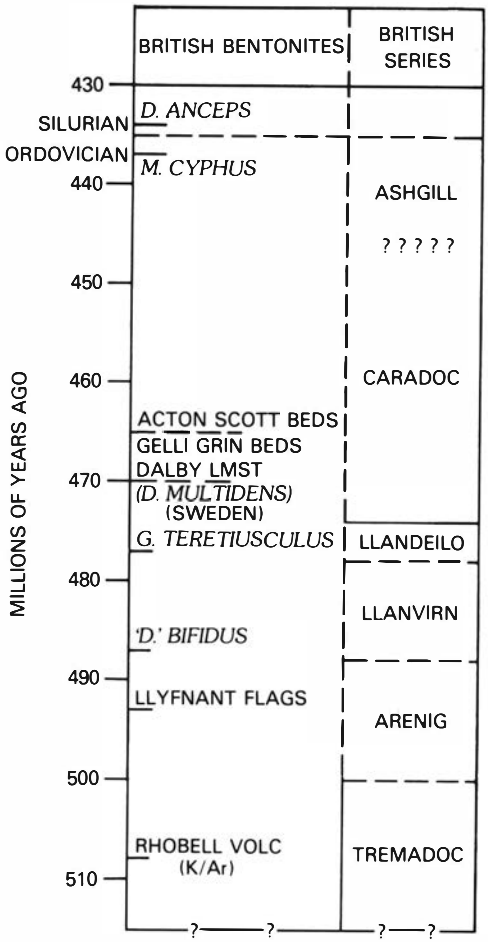

Figure 1 – British Ordovician fission-track dates and deduced ages of Series. Also date from Swedish Dalby Limestone (Zone of Diplograptus multidens*) and from Upper Tremadoc Rhobell Volcanics.*

North America problem dates

Other fission-track dates that do not seem to have been reset have produced puzzles for which we have yet to find the solutions. For a score of years the age of the Caradoc was based on isotopic dating of the *Chasmops* Limestone of Sweden – 450 m.y. (Byström-Asklund *et al.* 1961) and the Carters Limestone of Alabama. A fission track date on the latter is 454 ± 8 m.y. Two other Rocklandian formations in the Mississippi Valley averaged with the correlative Carters are dated by fission tracks at 453 ± 3 m.y. (Ross *et al.*, 1982; 146). By contrast the Actonian of the Onny River is dated at 466 ± 16 m.y. and the Longvillian near Bala 464 ± 13 m.y. Further, a sample collected by S. M. Bergström from the Dalby Limestone of Sweden (zone of *D. multidens* = Mid Caradoc?) is dated at 470 ± 10 m.y. by fission tracks (Figure 1). According to strict statistical practice these dates may not be significantly different, but there is a consistent suggestion that the North American Rocklandian dates are about 10 m.y. younger than the supposedly correlative Caradoc. In this same interval the graptolite zonation in the United States is the source of much disagreement (Ross, 1982; 2; Finney, 1982; 20–21). The shelly fauna of the type Caradoc is virtually unknown in North America. Is it possible that the isotopic dates are calling attention to a biostratigraphic miscorrelation? An attempt to obtain more evidence on this question by collecting two bentonites from the Rocklandian Tyrone Limestone of Kentucky produced fission track dates of 447 ± 15 m.y. and 462 ± 16 m.y., averaging 455 ± 15 m.y. and merely reinforced the problem, not its solution.

Chinese Ashgillian and North American Cambrian dates

During the visit to China of five members of the Subcommission on Ordovician Stratigraphy in 1978, Ross collected a sample from the lower Wufeng Shale with the assistance of Dr. Wang Xiaofeng and Dr. Ma Kuogan of the Geological Institute of Yichang. The collection was made on the north side of the Yangtze River and the west side of the Huanling anticline. The fission track date of this sample is 447 ± 10 m.y. If these beds are correctly correlated with the ear-

NORTH AMERICAN ORDOVICIAN FISSION TRACK DATES
AND DEDUCED RANGES OF STAGES

DATES OF FORMATIONS INCLUDE ANALYTICAL ERRORS

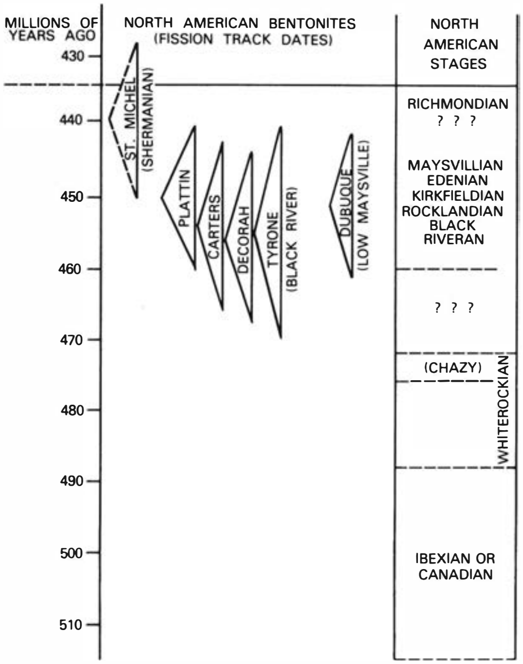

Figure 2 – North American Ordovician fission-track dates and one possible deduction of ages of Stages in the United States.

ly Ashgill, this date suggests that the Rocklandian is equivalent to the youngest Caradoc.

Two new fission track dates, both Middle Cambrian, are important in putting limits on the base of the Ordovician. Within the past two years Naeser has collected and dated a bentonite from the base of the Peach Spring Member of the Muav Limestone at 535 ± 12 m.y. (*Bathyuriscus – Bolaspidella*) and a bentonite from the *Glossopleura* zone of the low Bright Angel Shale at 563 ± 12 m.y. Both collections came from within the Grand Canyon of the Colorado River. As far as we know these are the only stratigraphically controlled Cambrian dates currently available.

Controversy

The publication of the fission track dating of the Series of the Ordovician and Silurian has been greeted almost immediately by controversy. Two examples, one involving yet another dating of the Ballantrae ophiolite complex of southwestern Scotland (Bluck *et al.*, 1980), and the other involving the dating of the Stockdale Rhyolite of northwestern England (Gale *et al.*, 1980), have prompted their authors to reject the fission track dates.

One of the most recent examples of the intuitive approach to dating is the work of Bluck *et al.* (1980), who have used isotopic dating to derive a revised history of the Ballantrae igneous complex. However, they have also noted the presence of a variety of clasts of metamorphic rocks interbedded in a black shale. Lithologic similarity led them to assume that the clasts were derived from the complex and that the shales were of the same age as shales 300 km distant in Ireland. In the Irish shales, not in the Scottish, graptolites of the Arenig zone of *Didymograptus nitidus* have been reported (Dewey *et al.*, 1970; 39–40). The metamorphic aureole of the complex was dated isotopically as 478 m.y. Therefore it was concluded that the date of the middle Arenig is 480 m.y. Here we do not question the isotopic date or that it is important in interpreting some important geologic event, probably in Llanvirn time. Using it to establish the time scale against which one is attempting to date the same sequence of geologic events is surely circular reasoning. Until 1978 this was the pragmatic approach to building an Ordovician time scale.

The Ashgill Stockdale Rhyolite has been dated at 421 ± 3 m.y. by the whole rock method of isotope analysis (Gale *et al.* 1980), resulting in their placement of the Ordovician-Silurian boundary at 418 m.y. Naeser (*in* Ross *et al.*, 1982; 147–149) has commented on this date. Wyborn and others (1982) have derived an isotopic date from the late Silurian early Ludlow Laidlaw Volcanics of southeastern Australia of 421 ± 3 m.y. The Laidlaw is composed of ignimbrite flows with minor airfall tuffs and has highly fossiliferous beds, containing conodonts as well as shelly fossils, both above and below. The fauna is correlated without question with the earliest Ludlow of Great Britain.

Very precise analysis has produced the following dates: K/Ar = 418.5 ± 1.9 m.y: Rb/Sr = 421.1 ± 1.3 m.y.. Rb/Sr = 424.5 ± 7.8 m.y. (whole rock).

Wyborn and coauthors consider 421 m.y. as "a precise estimate for the age of the earliest Ludlow". They comment on the identity of the date for the Stockdale Rhyolite (Gale *et al.*, 1979) and conclude that their very impressive data invalidate the Stockdale date as Ashgillian.

Summaries of previous time-scales

McKerrow *et al.* (1980) have presented the best modern summary of the status of the early Paleozoic time scale. We note with some satisfaction that they have made good use of Ordovician and Silurian dates published by Ross *et al.* (1978, now available with supporting data, 1982). Their graphic presentation includes a traditional distrust of and skepticism about isotopic dates. The horizontal axis, which we might consider a close approach to objectivity, is devoted to isotopic dates in millions of years. The other axis – the subjective axis – shows the relative lengths of stages and periods as estimated by the authors, based on rates of evolution for fossils and on rates of deposition of sedimentary rocks. Because the thicknesses of sedimentary rocks provide an almost instinctive measure of relative time when two similar sequences are compared, the subjective ordinate axis has been evolving since geologists first attempted to gauge the age of the earth. An early and surprisingly successful assembler of such data was Barrell (1917), who applied esti-

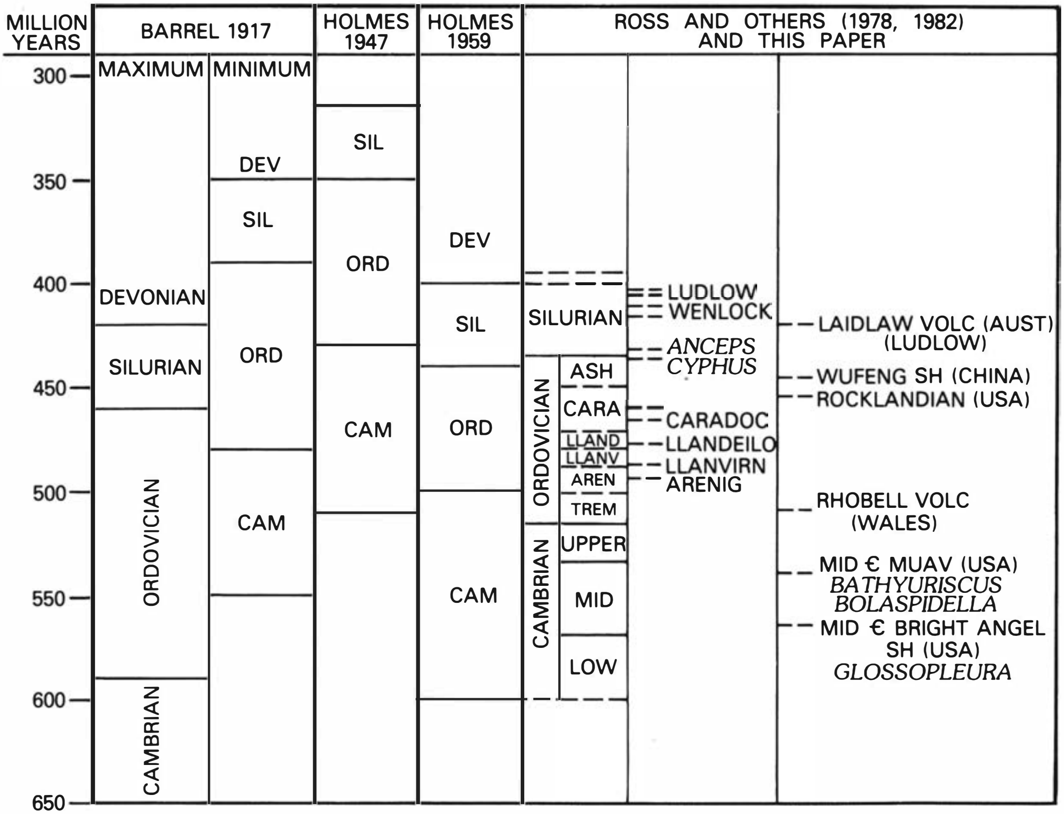

Table A – Comparison of dates for the early Paleozoic of Barrell (1917), of Holmes (1947, 1959), of Ross et al. *(1978 & 1982), and of this paper. Under Ross* et al., *left side shows deduced relative lengths of Series; two right columns show fission-track dates. Date of Laidlaw Volcanics tends to compress possible length of Silurian. Date of Ashgillian Wufeng Shale limits youngest Caradoc. Rocklandian dates correlate with youngest Caradoc. Date of Rhobell Volcanics lengthens duration of Ordovician at expense of Cambrian.*

mated minimum and maximum rates of sedimention to arrive at the estimated duration of each Period. Holmes (1947, see particularly Table III; 1959, 205–206, fig. 2) based his geologic time scale in a similar manner, taking stock of Barrell's efforts, but adding such isotopic constraints as were available. There has been some improvement over Holmes' results, as we have attempted to show in Table A.

McKerrow *et al.* (1980, Fig. 1, no. 10) have shown that our fission track date on the Acton Scott beds (466 ± 16 m.y.) does not conform to their straight line plot of all dates. They conclude (their Table 1) that the isotopic date should be younger, assuming that (1) they have correctly equated the Actonian with the zone of *D. clingani* and (2) they have proportioned that zone correctly within the Ordovician. To us the possibility is attractive that neither of these assumptions is correct, that the Actonian may be as old as the zone of *D. multidens* (= zones of *C. peltifer* + *C. wilsoni*), and that no part of the Caradoc is younger than 450 m.y. The last of these may be supported by our date on the Ashgillian Wufeng Shale (447 ± 12 m.y.)

The combination of the new Late Tremadocian date and the dates for the Middle Cambrian suggests that the age of the Cambrian-Ordovician boundary should be close to 515 m.y. Therefore the duration of the Ordovician Period seems to have approximated 80 m.y.

The future

Compston (1979) in a paper particularly important to biostratigraphers calls attention to a growing divergence between isotopic geochemists and stratigraphers. Compston charges biostratigraphers with the responsibility of selling the "scientific importance of numerical time scale work. They need to convince more isotope geologists of the need to direct their interests and research funds to stratigraphic applications; they should also engage them as early as possible in the project rather than at the end of one and as part time consultants".

Compston raises a question concerning importance of isotopic dating in the choice of stratotypes of internationally important boundaries. He might very well ask whether any of the proposed stratotypes for either boundary of the Ordovician System can be dated isotopically and whether that possibility should be given as much weight as the presence of any particular fossil phylum.

There may be easily dateable units, such as bentonite beds, in stratigraphic sections which are either ignored or unrecognized. It is the responsibility of the stratigrapher to call these beds to the attention of the isotope geologist.

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