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Fission-track dating of Lower Paleozoic volcanic ashes in British stratotypes

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INTRODUCTION

In order to establish a radiometric geochronology based on Lower Paleozoic British stratotypes, 41 collections of bentonites and other volcanically derived rocks were collected in five main areas of Ordovician and Silurian outcrops in Wales, England, and Scotland in September 1976. These are the areas studied by Sedgwick, Murchison, and Lapworth in establishing the Lower Paleozoic Systems on which our modern work is based.

Although only 12 of the 41 samples collected have been analyzed, they have provided minimum ages for the lower Arenig, lowest Llandeilo, and upper Caradoc Series of the Ordovician System, and for the lower Wenlock, uppermost Wenlock, and middle Ludlow Series of the Silurian System. The project, undertaken under the auspices of the U.S. Geological Survey and the National Geographic Society, has benefited from the indispensable participation of British colleagues who made certain that our stratigraphy was correct, and who ferreted out tuffs, ashes, and bentonites in numbers we hardly dreamed possible.

It was, and still is, our purpose to establish a radiometric geochronology of Early Paleozoic time, particularly of the Ordovician, using the fission-track method of dating bentonites and other volcanically derived strata in the British stratotypes. The British type sections are those against which all other Lower Paleozoic biostratigraphic sections throughout the world

are ultimately compared. Although much of our purpose has been accomplished, the analyses of most of the remaining collections are needed to strengthen or to rectify our present results.

About 15 kg of rock constituted each sample, considerably less than we had originally planned; the logistics of gathering samples at the end of field work in southern Scotland for consolidated shipment by air freight from London to Denver dictated a reduction in the size of collections. With a few exceptions, these seem to have been of adequate size to produce enough zircon crystals for analysis.

As shown in figure 1, there are four main areas of outcrop of the Ordovician System in Wales and England. To these we must add a fifth area east of Moffat, Dumfrieshire, Scotland, where bentonites are abundant. Each of these areas was visited after our arrival in London, on September 8th and 9th, and prior to the end of field work near Girvan, Ayrshire, on September 27, 1976.

AREAS OF INVESTIGATION

Bala District and Arenig Fawr, northern Wales--The first area visited was that in which we hoped to collect the oldest Ordovician rock, from the type section of the Arenig Series (figure 1) west of Bala, in northern Wales. Thanks to detailed mapping by D. A. Bassett, H. B. Whittington, and Alwyn Williams (1966) and to our good fortune in persuading Professor Whittington to be a partner in our efforts, 10 collections were made from ashes and tuffs of Early Arenigian, Llanvirnian, and Caradocian age. When analyzed, most of these collections will be compared

with others from southern Wales and Shropshire (or Salop). Details of their biostratigraphic positions are being verified by Jan Zalasiewicz under the guidance of Whittington.

The single sample already analyzed (no. 8) came from the Upper Arenig Henllan ash (fig. 1; fig. 2, column W. 5), from the west side of Arenig Fawr. Trilobites from the ash have been described by Whittington (1966). The radiometric age of the Henllan ash is at least 478 $\pm$ 27 m.y. according to Naeser. This age is reasonable; its very reasonableness indicates that ashes in the Bala District have not been as drastically heated as we feared and that age determinations from the other samples should be reliable.

Powys and Dyfed (southern Wales)--We next made 12 collections in southern Wales along the belt of outcrop from Llandrindod Wells to St. Davids (fig. 1; fig. 2, col. W. 8 to W. 12). So far, only four have been analyzed. In this large region, Dr. C. P. Hughes led us to 19 different localities at which volcanic strata had been described. At two localities we were unable to find the reported ashed. At five others the rock seemed so thoroughly indurated that separation of zircon crystals was thought to be impractical. The four samples analyzed gave mixed results.

The most rewarding collection of the four (no. 13) was taken from a thin bentonite layer in shales bearing Glyptograptus teretiusculus, in a stream section east of Bach-y-graig, near Llandrindod Wells.

Naeser has obtained an age of 463 $\pm$ 32 m.y. from the sample, which comes from the topmost Llanvirn or lowermost Llandeilo Series.

The area is under study by P. R. Sheldon, under the supervision of Hughes. Sheldon assisted in the collecting and will corroborate the precise biostratigraphic position of sample no. 13. Two other samples indicated that the rock had been heated after deposition, which may be significant in delineating Silurian or later tectonism. In the upper reaches of Howey Brook, near Builth Wells, a bentonite is present in a section first described by Murchison in 1839; it lies beneath shales carrying Didymograptus murchisoni and might have given an age for the Llanvirn Series. Regrettably, the fission-track age of 420 m.y. is probably Early Silurian. Similarly, rhyolitic ashes of the Llanvirnian Fairfach Group collected on Coed Duon Hill near Llandovery gave an age close to 400 m.y.; the rhyolite must have been heated secondarily until very latest Silurian or Early Devonian time. A fourth collection from the Arenigian Pwlluog volcanics, at Whitesands Bay, west of St. Davids, produced only three tiny zircon crystals, too few to permit an age determination. We were joined in the collecting at St. Davids by R. B. Rickards, under whose guidance C. J. Jenkins is mapping in the area.

Shropshire or Salop (Church Stretton, Wenlock Edge, and Ludlow)--On September 20th and 21st, collecting was concentrated mainly on the type sections of the Wenlock and Ludlow Series of the Silurian with the participation of Drs. L. R. M. Cocks, British Museum (Natural History); M. G. Bassett, National Museum of Wales; and Peter Toghill, University of Birmingham. In this area we had the great advantage of knowing that none of the bentonites had been heated above 80°C, and that any zircon or

apatite crystals should give satisfactory fission tracks for dating.

Eight Silurian collections were made, and three of these have already produced significant results. From the Buildwas Formation (basal Sheinwoodian) (fig. 3, col. J), close to the base of the Wenlock Series a bentonite (no. 23) has an age of 410 $\pm$ 32 m.y. Another bentonite, from the Much Wenlock Limestone Formation at the top of the Wenlock Series (no. 26), gave a minimum age of 404 $\pm$ 24 m.y. Separate analyses on different fractions of a collection (no. 28) from the top of the Bringewood Beds (Bringewoodian) in Sunnyhill Quarry, near Ludlow, produced ages of 398 $\pm$ 29 m.y. and 397 $\pm$ 31 m.y. The Bringewood Beds are close to the middle of the Ludlow Series. An estimated age of 395 m.y. is therefore not unreasonable for the top of the Silurian. We might also guess that the Ludlow Epoch was about 10 m.y. in length and the Wenlock, about 6 m.y. Unfortunately, we have obtained no samples from the Llandovery Series suitable for fission-track dating. Zircons from one Llandovery collection (no. 35) from the north side of the Onny River contain too many tracks to be counted. These zircons will be dated when possible, using the Pb-U method.

The original locality in the Acton Scott beds, Caradoc Series, of the Ordovician System, on the south side of the Onny River, was re-collected in the company of Dr. W. T. Dean, Geological Survey of Canada. A collection made by Ross in 1968, with Dr. Dean, was shown by Naeser to have a minimum age of 451 $\pm$ 21 m.y. (Ross, Naeser, and Izett, 1976). The result from the first of

our 1976 samples from the same locality is 454 ± 27 m.y. This becomes the youngest Ordovician age we have been able to determine.

Cautley District (Sedbergh, Cumbria)--In the company of Dr. J. Keith Ingham, Hunterian Museum, Glasgow University, a search was made for Cautley volcanic rocks of Ashgillian age containing zircon crystals. The search was not successful and the one sample (no. 36) could not be dated.

Moffat District, Dumfrieshire (Moffat Water, Dobbs Linn)--East of the town of Moffat in Dumfrieshire, Scotland, the section at Dobbs Linn was made famous by Lapworth in 1879; it exhibits a complete stratigraphic succession across the boundary from the topmost Ordovician Ashgill Series into the lowermost Silurian Llandovery Birkhill Shales. Furthermore, the transition from one to the other is interbedded with numerous bentonite layers. Three collections were made with Dr. Ingham. Only one (no. 40) has been analyzed by the fission-track method; the resulting age is 320 m.y. The tracks have been "reset" as a result of heating during the Caledonian Orogeny prior to 320 m.y. ago. Although the Ordovician-Silurian boundary cannot be dated by fission tracks at this locality an age can probably be determined by the Pb-U method.

SUMMARY

For the first time radiometric dates have been obtained from bentonites interstratified within the type sections of two Lower Paleozoic Systems. The ages obtained, using the fission-track

method, are in the proper order and of reasonable magnitude. We suspect that the estimates of possible analytical error are excessive.

The ages obtained at the time of this preliminary report were based on only 10 of the 41 samples made from Ordovician and Silurian strata in northern and southern Wales, in Salop (Shropshire), in Cumbria, and in Southern Uplands of Scotland. Although we know that two collections cannot produce a correct age using the fission-track method (Llandovery on the Onny River: Ashgill-Llandovery at Dobbs Linn), they probably will give reliable ages using the lead-uranium method of analysis.

Of those collections not yet analyzed, the greatest promise is given by those from the Bala District, now that we know they are probably not "reset" by overheating. They may provide ages for the Llanvirn and for the lower parts of the Caradoc Series.

Our preliminary results are shown graphically - (Ages in parentheses are estimated):

REFERENCES CITED

Bassett, D. A., Whittington, H. B., and Williams, Alwyn, 1966, The stratigraphy of the Bala District, Merionethshire: Quart. Jour. Geol. Soc. London, v. 122, p. 219-271.

Bassett, M. G., Cocks, L. R. M., Holland, C. H., Rickards, R. B., and Warren, P. T., 1975, The type Wenlock Series: Instit. Geol. Sciences, Rept. no. 75/13, 19 p.

Cocks, L. R. M., Holland, C. H., Rickards, R. B., and Strachan, Isles, 1971, A correlation of Silurian rocks in the British Isles: Geol. Soc. London Spec. Rept. no. 1, Jour. Geol. Soc., v. 127, p. 103-136.

Ross, R. J., Jr., Naeser, C. W., and Izett, G. A., 1976, Apatite fission-track dating of a sample from the type Caradoc (Middle Ordovician) Series in England: Geol. Soc. America, Geology, v. 4, p. 505-506.

Whittington, H. B., 1966, Trilobites of the Henllan Ash, Arenig Series, Merioneth: Bull. British Mus. (Nat. Hist.), Geology, v. 11, no. 10, p. 489-505, 5 pls.

Williams, Alwyn; Strachan, Isles; Bassett, D. A., Dean, W. T., Ingham, J. K., Wright, A. D., and Whittington, H. B., 1972, A correlation of Ordovician rocks in the British Isles: Geol. Soc. London, Spec. Rept. no. 3, 74 p.

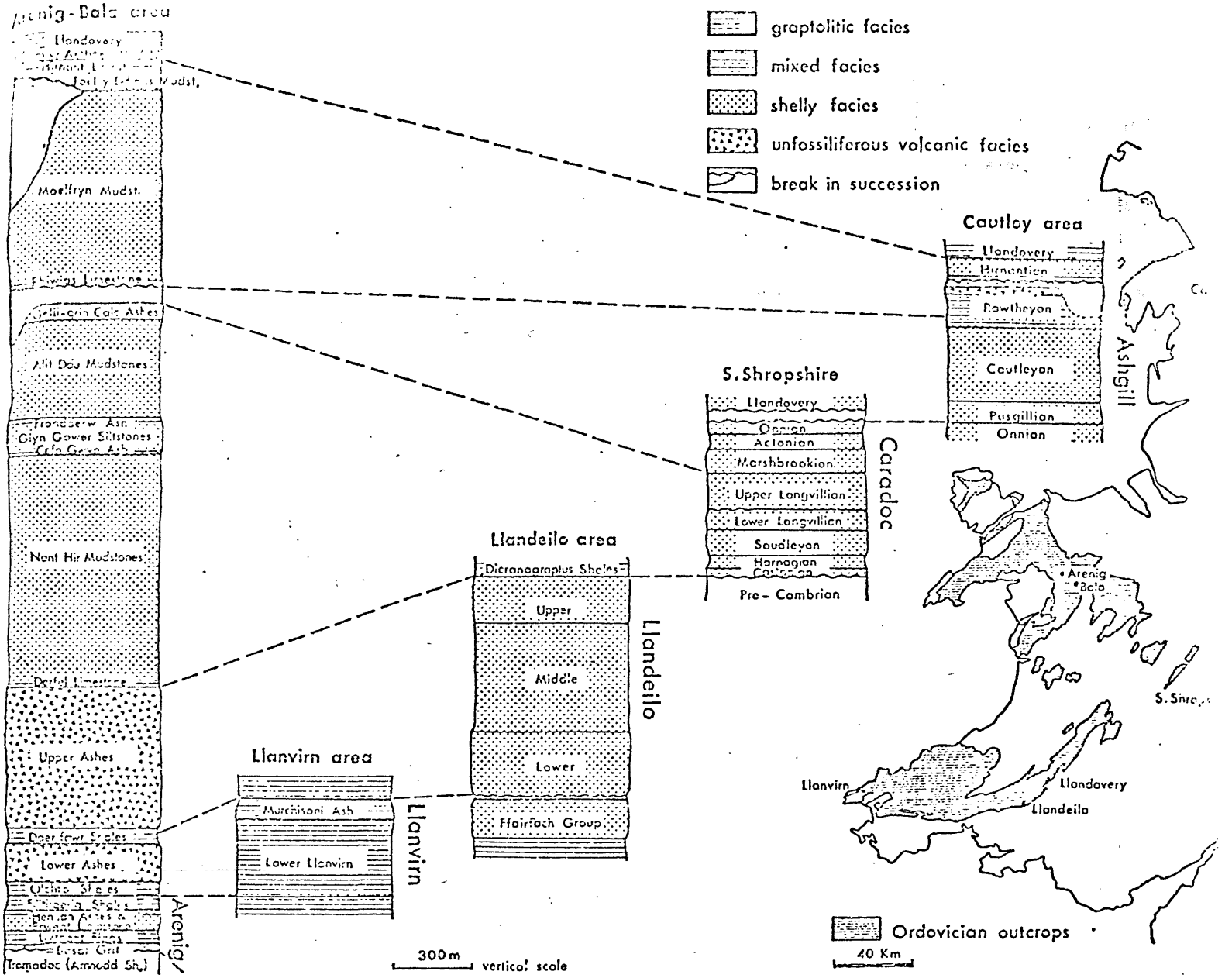

Figure 1 - Correlation of the standard sections of the various Ordovician series of England and Wales (after Williams and others, 1972)

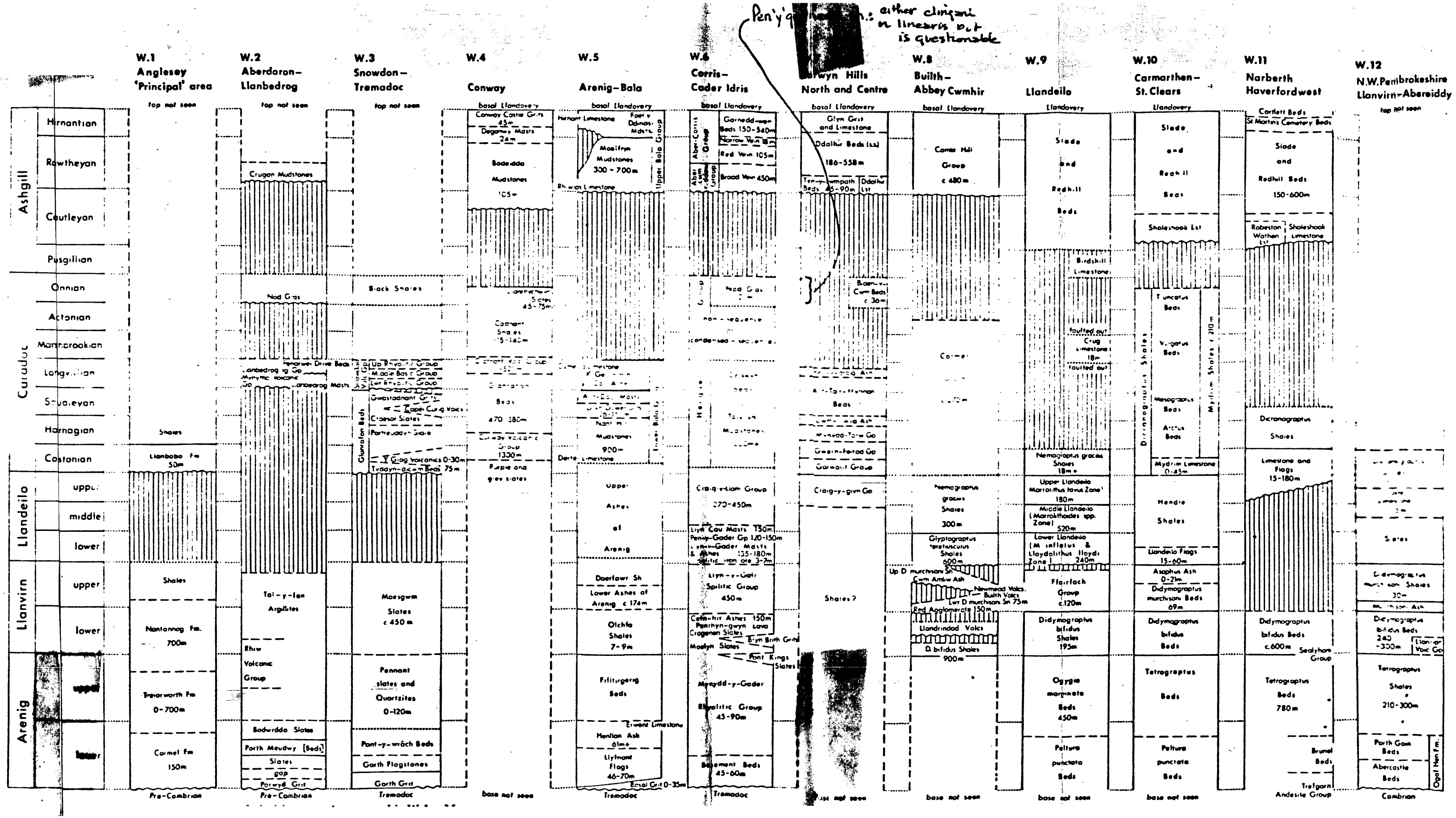

Figure 2 - Correlation of the Ordovician successions in Wales. This project is concerned with columns W.5, W.8-W.12 (after Williams and others, 1972)

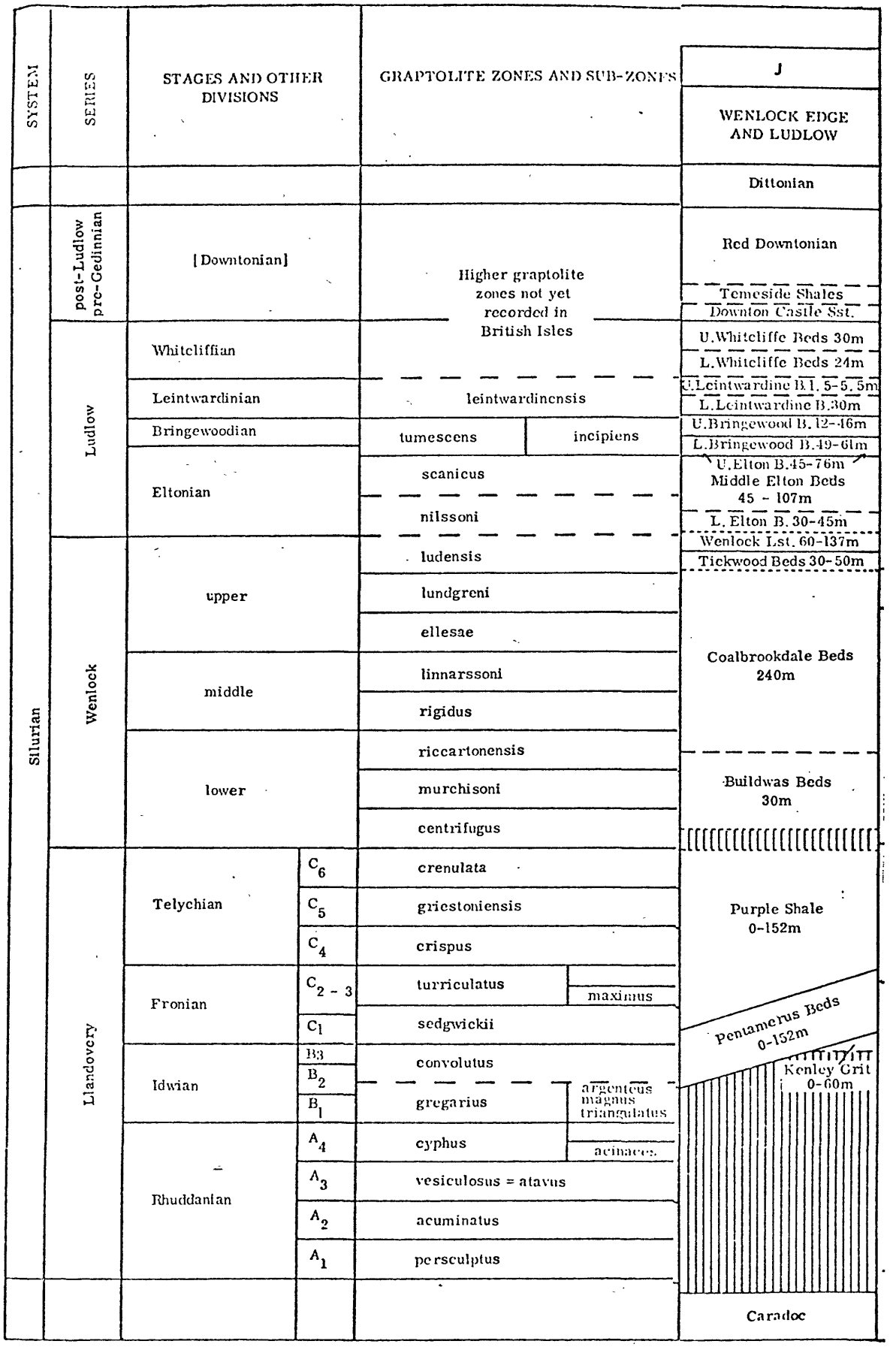

Figure 3 - Succession of Silurian units exposed from Wenlock Edge to Ludlow, Shropshire (Salop). (extracted from Cocks and others, 1971, fig. 2)