**DATA REPOSITORY 2010087**

*Materials and Methods*

Our study is based on Upper Ordovician conodonts from Minnesota, Kentucky, and southern Ohio (Fig. DR1). The samples from Minnesota were collected between 1958 and 1964 by G.F. Webers, R.E.Sloan and R. Bleifuss at selected localities (for detailed description of outcrops and lithostratigraphic units, see Webers, 1966; for stratigraphic revisions, see Sweet, 1979). The samples from Kentucky and Ohio are from three overlapping sections (Frankfort East, Bear Creek, and Moffett Road) and were collected by S.M., Bergström, W.C. Sweet, J. Pojeta, Jr., and others during the 1960s and 1970s (for detailed description of outcrops and lithostratigraphic units, see Bergström and Sweet, 1966; Sweet, 1984).

Conodonts (0.5 to1 mg) were dissolved in nitric acid and chemically converted to $Ag_3PO_4$ using a modified version of the method described by O'Neil et al. (1994). Oxygen isotope ratios were measured on CO using a High Temperature Conversion Elemental Analyser (TC-EA) connected online to a ThermoFinnigan Delta plus mass spectrometer. All $\delta^{18}O$ values are reported in per mil relative to V-SMOW (Vienna Standard Mean Ocean Water). Accuracy and reproducibility of the measurements ($1\sigma = \pm 0.2‰$) were monitored by multiple analyses of NBS120c and several phosphate reference samples (for details, see Joachimski et al., 2004). Palaeotemperatures were calculated using the equation given by Kolodny et al. (1983).

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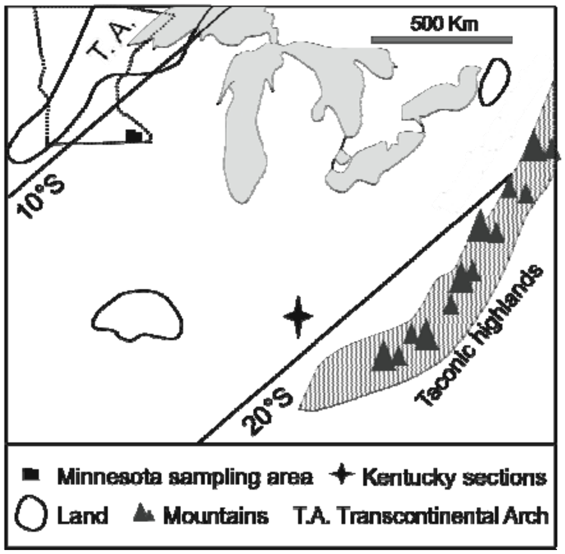


Fig. DR1. Location of studied sections in Minnesota and Kentucky.

Table DR1: $\delta^{18}O$ values of conodonts from studied sections in Kentucky and Minnesota

| **Frankfort East Section (Section 64S2)** | | | **Bergström & Sweet (1966)** | | |
|---|---|---|---|---|---|
| FE samples (Lexington Limestone) | | | | | |
| **sample** | **Formation** | **level** | **m above base of Lexington Lst.** | **conodont zone** | **$\delta^{18}O$ ‰VSMOW** |
| | | | | | |
| FE 6 | Curdsville Mbr. | bed 6 | 0.00 | *Phragmodus undatus* | 19.0 |
| FE 8 | Curdsville Mbr. | bed 8 | 1.83 | *Phragmodus undatus* | 19.4 |
| FE 9 | Curdsville Mbr. | bed 9 | 2.74 | *Phragmodus undatus* | 19.0 |
| FE 11 | Logana Mbr. | bed 11 | 10.37 | *Plectodina tenuis* | 19.3 |
| FE 12 | Logana Mbr. | bed 12 | 10.98 | *Plectodina tenuis* | 19.5 |
| FE 13 | Logana Mbr. | bed 13 | 11.89 | *Plectodina tenuis* | 18.9 |
| FE 14+15 | Logana Mbr. | beds 14+15 | 14.02 | *Plectodina tenuis* | 19.6 |
| FE 16 | Logana Mbr. | bed 16 | 15.85 | *Plectodina tenuis* | 18.9 |
| FE 17 | Logana Mbr. | bed 17 | 16.77 | *Plectodina tenuis* | 18.8 |
| FE 18 | Grier Mbr. | bed 18 | 17.99 | *Plectodina tenuis* | 19.7 |
| FE 19 | Grier Mbr. | bed 19 | 18.90 | *Plectodina tenuis* | 18.4 |
| FE 22 | Grier Mbr. | bed 22 | 21.65 | *Plectodina tenuis* | 19.2 |
| FE24 | Grier Mbr. | bed 24 | 23.78 | *Plectodina tenuis* | 19.4 |
| FE 26 | Grier Mbr. | bed 26 | 25.00 | *Plectodina tenuis* | 19.1 |
| FE 29 | Grier Mbr. | bed 29 | 27.74 | *Plectodina tenuis* | 19.0 |
| FE 32 | Grier Mbr. | bed 32 | 30.49 | *Plectodina tenuis* | 19.2 |
| FE 36 | Grier Mbr. | bed 36 | 32.93 | *Plectodina tenuis* | 18.9 |
| FE 41 | Grier Mbr. | bed 41 | 38.41 | *Plectodina tenuis* | 18.2 |
| FE 44 | Grier Mbr. | bed 44 | 41.46 | *Plectodina tenuis* | 18.6 |
| FE 48 | Grier Mbr. | bed 48 | 59.76 | *Belodina confluens* | 18.6 |
| FE 53+54 | Tanglewood Mbr. | beds 53+54 | 64.79 | *Belodina confluens* | 18.9 |
| FE 56+57 | Tanglewood Mbr. | beds 56+57 | 67.53 | *Belodina confluens* | 18.8 |

| | | | | | |
|---|---|---|---|---|---|
| FE 60+61 | Tanglewood Mbr. | beds 60+61 | 71.65 | *Belodina confluens* | 18.0 |
| FE 63-65 | Tanglewood Mbr. | beds 63 to 65 | 74.09 | *Belodina confluens* | 18.4 |
| FE 71+72 | Tanglewood Mbr. | beds 71+72 | 81.71 | *Belodina confluens* | 18.3 |
| FE 75+76 | Tanglewood Mbr. | beds 75+76 | 85.06 | *Belodina confluens* | 19.0 |
| FE 78 | Tanglewood Mbr. | bed 78 | 87.50 | *Belodina confluens* | 18.5 |
| FE 81+82 | Tanglewood Mbr. | beds 81+82 | 90.70 | *Belodina confluens* | 18.5 |
| FE 84+85 | Tanglewood Mbr. | beds 84+85 | 93.45 | *Belodina confluens* | 18.3 |

| **Bear Creek Section (60 BCK)** | | | **Bergström & Sweet (1966)** | |
|---|---|---|---|---|
| **sample** | **Formation** | **m above base of Kope Fm** | **conodont zone** | **$\delta^{18}O$ ‰VSMOW** |
| | | | | |
| BCK 76+78 | Point Pleasant Fm | -1.52 | *Amorphognathus superbus* | 18.9 |
| BCK 82 | Kope | 0.00 | *Amorphognathus superbus* | 19.7 |
| BCK 83 | Kope | 0.30 | *Amorphognathus superbus* | 19.1 |
| BCK 88 | Kope | 1.83 | *Amorphognathus superbus* | 18.9 |
| BCK 91 | Kope | 2.74 | *Amorphognathus superbus* | 19.0 |
| BCK 97 | Kope | 4.57 | *Amorphognathus superbus* | 19.0 |
| BCK 105.5 | Kope | 7.16 | *Amorphognathus superbus* | 18.9 |
| BCK 109 | Kope | 8.23 | *Amorphognathus superbus* | 19.2 |
| BCK 112+114 | Kope | 9.76 | *Amorphognathus superbus* | 18.3 |

| **Moffett Road Section (60 BCK). Kenton County, Kentucky** | | | | **Sweet (1984)** | |
|---|---|---|---|---|---|
| **sample** | **Formation** | **USGScollections - slide No.** | **m above base of Kope Fm** | **conodont zone** | **$\delta^{18}O$ ‰VSMOW** |
| | | | | | |
| MR 4 | Point Pleasant | 8400-CO | -15,24 | *Amorphognathus superbus* | 18.5 |
| MR 7 | Point Pleasant | 8405-CO | -14.12 | *Amorphognathus superbus* | 19.7 |
| MR 13 | Point Pleasant | 8409-CO | -12.41 | *Amorphognathus superbus* | 18.7 |
| MR 17 | Point Pleasant | 8414-CO | -11.49 | *Amorphognathus superbus* | 19.1 |
| MR 26 | Point Pleasant | 8420-CO | -8.48 | *Amorphognathus superbus* | 18.5 |
| MR 28 | Point Pleasant | 8422-CO | -7.87 | *Amorphognathus superbus* | 18.7 |
| MR 32 | Point Pleasant | 8427-CO | -6.86 | *Amorphognathus superbus* | 18.9 |
| MR 38 | Point Pleasant | 8433-CO | -4.85 | *Amorphognathus superbus* | 18.6 |
| MR 43 | Point Pleasant | 8440-CO | -3.38 | *Amorphognathus superbus* | 18.9 |
| MR 47 | Point Pleasant | 8444-CO. 8445-CO | -2.29 | *Amorphognathus superbus* | 18.7 |
| MR 50 | Point Pleasant | 8447-CO | -1.13 | *Amorphognathus superbus* | 18.8 |
| MR 56 | Kope | 8452-CO | 0.58 | *Amorphognathus superbus* | 19.1 |
| MR 61 | Kope | 8456-CO | 2.07 | *Amorphognathus superbus* | 18.5 |
| MR 68 | Kope | 8459-CO. 8460-CO | 4.21 | *Amorphognathus superbus* | 18.8 |
| MR 77 | Kope | 8467-CO | 7.07 | *Amorphognathus superbus* | 18.7 |
| MR 88 | Kope | 8475-CO | 10.12 | *Amorphognathus superbus* | 19.2 |
| MR 96 | Kope | 8481-CO | 12.71 | *Amorphognathus superbus* | 18.7 |
| MR 106 | Kope | 8492-CO | 15.95 | *Amorphognathus superbus* | 18.6 |
| MR 111 | Kope | 8495-CO | 17.38 | *Amorphognathus superbus* | 19.0 |
| MR 124 | Kope | 8507-CO | 21.40 | *Amorphognathus superbus* | 18.5 |
| MR 127 Pt | Kope | 8510-CO. 8512-CO | 22.16 | *Amorphognathus superbus* | 18.4 |
| MR 127 Ds | Kope | 8510-CO. 8512-CO. 8516-CO. 8518-CO. 8522-CO | 22.87 | *Amorphognathus superbus* | 18.0 |
| MR 132 A | Kope | 8522-CO | 23.63 | *Amorphognathus superbus* | 18.8 |

| | | | | | |
|---|---|---|---|---|---|
| MR 132 P | Kope | 8522-CO. 8523-CO | 23.78 | *Amorphognathus superbus* | 18.5 |
| MR 140 | Kope | 8531-CO | 26.19 | *Amorphognathus superbus* | 19.1 |
| MR 147 | Kope | 8538-CO | 28.38 | *Amorphognathus superbus* | 18.4 |
| MR 169 | Kope | 8544-CO | 35.21 | *Amorphognathus superbus* | 19.0 |
| MR 184 | Kope | 8547-CO | 39.79 | *Amorphognathus superbus* | 18.6 |
| MR 199 | Kope | 8549-CO | 44.36 | *Amorphognathus superbus* | 18.6 |
| MR 212 | Kope | 8554-CO | 48.57 | *Amorphognathus superbus* | 18.5 |
| MR 235 | Kope | 8557-CO | 55.37 | *Amorphognathus superbus* | 18.6 |
| MR 250 | Kope | 8562-CO | 59.94 | *Amorphognathus superbus* | 18.5 |
| MR 258 | Kope | 8568-CO | 62.32 | *Amorphognathus superbus* | 18.9 |
| MR 273 | Kope | 8580-CO | 66.95 | *Amorphognathus superbus* | 19.1 |
| MR 288 | Kope | 8592-CO | 71.43 | *Amorphognathus superbus* | 18.9 |
| MR 319 | Fairview | 8612-CO. 8613-CO | 81.01 | *Amorphognathus superbus* | 18.7 |
| MR 341 | Fairview | 8623-CO | 87.62 | *Amorphognathus superbus* | 18.7 |

| **Minnesota samples (details concerning sections see Webers 1966)** | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| **sample** | **m in section** | **Formation** | **conodont $\delta^{18}$O ‰VSMOW** | **conodont species** | **fish tooth $\delta^{18}$O ‰VSMOW** |
| | | | | | |
| Pl1 | 3.41 | Pecatonia | | | |
| PL10/11 | 3.50 | McGregor | 19.5 | | |
| Pl12 | 6.92 | McGregor | 19.6 | | |
| Pl13 | 7.38 | McGregor | 19.7 | | |
| Pl14 | 7.56 | Carimona | 19.6 | *Belodina compressa* | |
| Pl14 | 7.56 | Carimona | 19.8 | *Polyplacognathus* sp. | |
| Pl14A | 7.56 | Carimona | 19.8 | *Polyplacognathus* sp.. bifurcate Form | |
| Pl16 | 7.80 | Carimona | 20.5 | | |
| Pl16A | 7.80 | Carimona | 20.0 | | |
| Pl17 | 7.88 | Carimona | 19.8 | | |
| Pl17 | 7.88 | Carimona | 20.2 | | |
| Pl17/18 | 8.19 | Carimona | 20.2 | | |
| Pl19 | 8.31 | Carimona | 19.9 | | |
| Pl20 | 8.55 | Carimona | 20.0 | | |
| Pl21/22 | 8.61 | Carimona | 20.1 | | |
| Pl23 | 8.83 | Carimona | 19.8 | | |
| Pl24 | 8.98 | Carimona | 20.0 | | |
| Pl25 | 9.13 | Carimona | 20.0 | | |
| Pl26 | 9.19 | Carimona | 20.3 | | |
| De1 | 9.49 | Decorah shale | 19.6 | | 19.5 |
| De2 | 9.80 | Decorah shale | 18.6 | | |
| De3 | 10.10 | Decorah shale | 19.0 | | |
| De4 | 10.41 | Decorah shale | 19.0 | | |
| De6 | 11.02 | Decorah shale | 19.4 | | 18.2 |
| De7 | 11.32 | Decorah shale | 19.7 | | |
| De8/9 | 11.63 | Decorah shale | 19.1 | | 19.5 |
| De9 | 11.93 | Decorah shale | | | 19.4 |
| De10 | 12.24 | Decorah shale | 19.4 | | |
| De10 | 12.24 | Decorah shale | 19.3 | | |
| De11 | 12.54 | Decorah shale | 19.5 | | |
| De12/13 | 12.85 | Decorah shale | 19.0 | | |
| De14 | 13.46 | Decorah shale | 19.1 | | |
| De14 | 13.46 | Decorah shale | 18.4 | | |
| De14A | 13.46 | Decorah shale | 19.5 | | |
| De16 | 14.07 | Decorah shale | 19.0 | | |
| De17/18 | 14.37 | Decorah shale | 19.7 | | |
| De19 | 14.98 | Decorah shale | 18.8 | | |
| De19 | 14.98 | Decorah shale | 18.4 | | |

| | | | | | |
|---|---|---|---|---|---|
| De21 | 15.59 | Decorah shale | 19.2 | | |
| De22 | 15.90 | Decorah shale | 18.9 | | |
| De24 | 16.51 | Decorah shale | 19.2 | | |
| De26 | 17.12 | Decorah shale | 19.3 | | |
| De27 | 17.42 | Decorah shale | 18.8 | | |
| De28-31 | 18.03 | Decorah shale | 19.6 | | |
| De32 | 18.95 | Decorah shale | 19.3 | | |
| De33 | 19.25 | Decorah shale | 18.5 | | |
| De34 | 19.56 | Decorah shale | 19.0 | | |
| De35 | 19.86 | Decorah shale | 18.8 | | |
| De37 | 20.47 | Decorah shale | 18.8 | | |
| De38 | 20.78 | Decorah shale | 19.0 | | |
| De39 | 21.08 | Decorah shale | 18.8 | | |
| De45 | 22.76 | Decorah shale | 18.8 | | |
| Cu16/17 | 30.87 | Cummingsville | 19.3 | | |
| Cu18/19 | 31.42 | Cummingsville | 19.1 | | |
| Cu20-22 | 31.84 | Cummingsville | 19.7 | | |
| Cu24/25 | 33.31 | Cummingsville | 19.6 | | |
| Cu26/28 | 34.53 | Cummingsville | 18.9 | | |
| Cu29/30 | 35.62 | Cummingsville | 19.5 | | |
| Cu31/32 | 37.15 | Cummingsville | 19.3 | | |
| Cu33 | 38.58 | Cummingsville | 19.3 | | |
| Cu33A | 38.58 | Cummingsville | 19.0 | | |
| Cu34-36 | 39.22 | Cummingsville | 19.3 | | |
| Cu35 | 39.80 | Cummingsville | 19.3 | | |
| Cu37 | 40.93 | Cummingsville | 19.3 | | |
| Cu38 | 41.39 | Cummingsville | 19.3 | | |
| Rh1-4/6 | 42.00 | Prosser | 18.1 | | |
| Rh7/8 | 44.26 | Prosser | 18.7 | | |
| Rh9/10 | 45.48 | Prosser | 18.6 | | 18.4 |
| Rh10 | 46.33 | Prosser | 18.8 | | |
| Rh11/12 | 46.70 | Prosser | 18.5 | | |
| Rh13 | 47.88 | Prosser | | | |
| Rh14/15 | 48.19 | Prosser | 19.2 | | |
| Rh16/18 | 49.74 | Prosser | 18.0 | | |
| Rh19 | 50.75 | Prosser | 18.7 | | |
| Rh20 | 51.30 | Stewartville | 18.8 | | |
| Rh21 | 51.57 | Stewartville | 18.6 | | |
| Rh22-25 | 51.91 | Stewartville | 19.1 | | |
| Rh26-28 | 52.95 | Stewartville | 19.2 | | |
| Rh29 | 54.68 | Stewartville | 18.4 | | |
| Rh30 | 55.45 | Stewartville | 19.0 | | 19.2 |
| Rh31-33 | 56.18 | Stewartville | 18.6 | | |
| Rh34-39 | 58.43 | Stewartville | 18.3 | | |
| Rh40-46 | 63.52 | Stewartville | 19.1 | | |
| Rh47-49 | 68.95 | Stewartville | 19.2 | | |
| Rh49-50 | 69.90 | Stewartville | 19.4 | | |
| Rh51-52 | 71.39 | Stewartville | 18.8 | | |
| Rh54-55 | 73.10 | Stewartville | 18.7 | | |
| Rh56 | 73.62 | Stewartville | 19.3 | | |
| Wr8 | 74.31 | Dubuque | 19.6 | | |
| Wr9 | 74.32 | Dubuque | 19.3 | | |
| Wr23-26 | 76.19 | Dubuque | 19.4 | | |
| Wr27 | 76.29 | Dubuque | 20.0 | | |
| Wr28/29 | 76.78 | Dubuque | 19.6 | | |
| Wr31/32 | 76.99 | Dubuque | 19.5 | | |
| Wr33 | 77.28 | Dubuque | 19.6 | | |
| Wr35 | 77.53 | Dubuque | 19.2 | | |
| Wr36 | 77.69 | Dubuque | 19.8 | | |
| Wr38 | 77.90 | Dubuque | 19.9 | | |

| | | | | | |
|---|---|---|---|---|---|
| Wr39 | 78.02 | Dubuque | 20.0 | | |
| Wr40 | 78.17 | Dubuque | 19.8 | | |
| Wr42 | 78.47 | Dubuque | 19.8 | | |
| Wr43 | 78.60 | Dubuque | 19.9 | | |
| Wr45 | 78.82 | Dubuque | 19.2 | | |
| Wr47 | 79.11 | Dubuque | 19.4 | | |
| Wr50 | 79.70 | Dubuque | 19.7 | | |
| Wr51 | 79.90 | Dubuque | 19.5 | | |
| Wr52 | 80.07 | Dubuque | 19.6 | | |
| Wr53/54 | 80.12 | Dubuque | 20.2 | | |
| Wr58 | 80.82 | Dubuque | 19.9 | | |
| | | | | | |
| WR 59A | 81.09 | Dubuque | 19.9 | *Panderodus gracilis* | |
| WR 59B | 81.09 | Dubuque | 19.7 | *Icriodella superba* | |
| WR 59C | 81.09 | Dubuque | 19.4 | mixed | |
| WR 59D | 81.09 | Dubuque | 19.6 | *Phragmodus cognitus* | |
| Wr60 | 81.17 | Dubuque | 20.0 | | |
| Wr61 | 81.24 | Dubuque | 19.4 | | |
| Wr63 | 81.57 | Dubuque | 20.1 | | |
| WR 65 base | | Dubuque | 20.2 | | |
| Wr65 | 81.97 | Dubuque | 19.4 | | |
| Wr66/67 | 82.00 | Dubuque | 19.8 | | |
| Wr67 | 82.25 | Dubuque | 19.8 | | |
| Wr68-70 | 82.56 | Dubuque | 19.7 | | |
| Wr71 | 82.89 | Dubuque | 19.5 | | |
| Wr75 | 83.47 | Dubuque | 19.6 | | |
| Wr76 | 83.47 | Dubuque | 19.7 | | |
| Wr78A | | Dubuque | 19.8 | | |

Table DR2: Additional samples from other localities

| Sample | Locality/Stratigraphy | Position | $\delta^{18}O_{apatite}$ ‰VSMOW |
|---|---|---|---|
| JR 3-14 81G | Carters Lst. - Tennessee | Immediately above Deicke | 19.9 |
| SAL 92 FF1 | Tyrone Formation, Dead Horse Quarry at the end of the Hwy 127 road cut in Lexington, Kentucky | 0-5 cm above Deicke | 19.9 |
| 09 B1-1 | | 5-10 cm above Deicke | 19.3 |
| 09 B1-2 | | 1 m above Deicke | 19.6 |

Table DR3: Stratigraphic correlation of the Minnesota and Kentucky sections. Correlation is based on Deicke and Millbrig horizons, GICE and conodont biostratigraphy.