High-Resolution Carbon-Isotope Stratigraphy of the Cambrian–Ordovician GSSP: An Enhanced International Correlation Tool

Karem Azmy, Gabriella Bagnoli, Svend Stouge and Uwe Brand

Abstract Isotope curves delineating $\delta^{13}C_{carb}$ and $\delta^{16}O$ variations across the Cambrian–Ordovician boundary at Green Point, western Newfoundland (Canada) are presented. The $\delta^{13}C_{carb}$ profile of the section reveals a composite (three peaks) negative shift of $\sim$6.0 ‰ and starts immediately at the base of bed 23 of the Broom Point Member. The $^{13}C_{carb}$ profile ties to conodont and graptolite zones and indicates that the lowest occurrence of planktic graptolites in Bed 25 largely coincides with the *C. lindstromi s.l.* conodont Zone, that is, below the ?*Iapetognathus* conodont Zone.

Keywords $^{13}C_{carb}$ isotope curve · Trace-element geochemistry · Green Point Formation · Cambrian–Ordovician GSSP

K. Azmy (✉)
Department of Earth Sciences, Memorial University of Newfoundland, St. John's, NL A1B 3X5, Canada
e-mail: kazmy@mun.ca

G. Bagnoli
Dipartimento di Scienze della Terra, Università di Pisa, via Santa Maria 53, 56126 Pisa, Italy
e-mail: bagnoli@dst.unipi.it

S. Stouge
Geological Museum, University of Copenhagen, Øster Voldgade 5, DK-1350 Copenhagen K, Denmark
e-mail: svends@snm.ku.dk

U. Brand
Department of Earth Sciences, Brock University, St. Catharines, ON L2S 3A1, Canada
e-mail: ubrand@brocku.ca

R. Rocha et al. (eds.), *STRATI 2013*, Springer Geology,
DOI: 10.1007/978-3-319-04364-7_47,

Introduction

The Green Point section of the Cow Head Group in western Newfoundland, Canada (Fig. 1) is composed of a nearly complete succession of fine-grained marine clastic and carbonate sediments that were deposited during the late Cambrian and Early Ordovician. The section serves as the GSSP for the global Cambrian–Ordovician system boundary (Cooper et al. 2001) and has been biostratigraphically well studied (Barnes 1988; Erdtmann 1988; Cooper et al. 2001). Recently, the exact stratigraphic level of the boundary, based on conodont biozonation, has been an issue of debate (Terfelt et al. 2012).

A $\delta^{13}C_{carb}$ curve from the Green Point section has not been published, because the data were not considered reliable (Cooper et al. 2001). Hence, the main purpose of this contribution is to present a high-resolution $\delta^{13}C_{carb}$ isotope curve for the Cambrian–Ordovician boundary interval sediments exposed at Green Point, Newfoundland, and to relate the new isotope curve to existing and important global biostratigraphic horizons coeval with the Green Point GSSP.

Geological Setting: Stratigraphy and Depositional Facies

The mid-Cambrian to Middle Ordovician strata of the Cow Head Group (up to 500 m thick) are deep-water deposits that accumulated along the Laurentian margin. The sediments are composed of interbedded shale and limestone, but significant conglomerate beds containing blocks of shallow-water carbonates were transported into the deep-water facies.

The marine distal slope Green Point Formation of the Cow Head Group consists of the Martin Point (lower), Broom Point (middle), and St. Pauls (upper) members. Shale and minor mud limestone dominate the Martin Point Member, the Broom Point Member is a ribbon to parted lime mudstone with beds of grainstone, conglomerate, and siltstone, and the overlying St. Pauls Member includes red and green shales and minor carbonates (James and Stevens 1986). The two lower members of the Green Point Formation are exposed at Green Point (Fig. 2) and the succession represents the base of a slope depositional environment (James and Stevens 1986).

Biostratigraphy

The succession at Green Point was deposited during the *Eoconodontus notchpeakensis* to *Cordylodus intermedius* conodont biozones (Furongian Series, uppermost Cambrian) and the *C. lindstromi s.l.* and *Cordylodus angulatus* conodont Biozone (Tremadocian Stage, Lower Ordovician) (Barnes 1988; Terfelt et al. 2012).

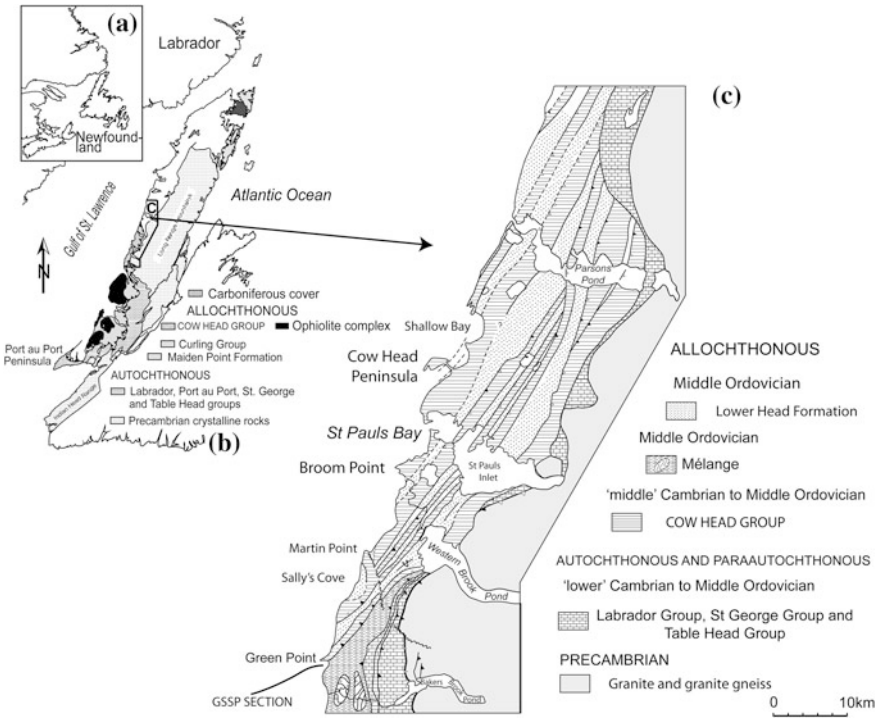

Fig. 1 Location map showing the study area

The GSSP horizon with the golden spike in bed 23 is placed in the *C. hintzei* Subzone of the *Cordylodus intermedius* Zone (Fig. 2; Terfelt et al. 2012). The first planktonic graptolites (i.e., *Rhabdinopora praeparabola* and *Staurograptus dichotomus*) occur in bed 25 (Erdtmann 1988; Cooper et al. 2001), which is about 5 m above the global Cambrian–Ordovician boundary horizon in the Green Point section (Fig. 2).

Materials and Methods

Eighty-four samples composed of lime mudstone were collected from and logged into the Green Point section starting at the top of bed 17 (Fig. 2). The degree of preservation of the studied micritic carbonates of the Green Point Formation was evaluated by petrographic and geochemical multiscreens following the protocol described in Azmy et al. (2010). The total rare earth element ($\sum$REE) contents of carbonates are enriched by diagenesis (Azmy et al. 2011) and are, along with their Mn and Sr counterparts, a powerful tool in recognizing alteration in extreme deep-time carbonates.

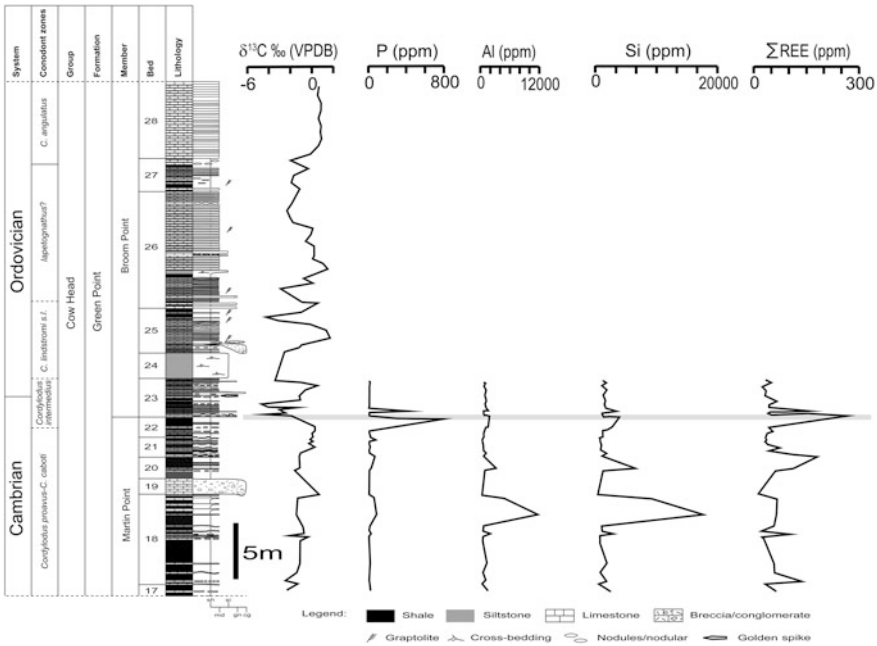

Fig. 2 Diagram showing the $\delta^{13}C$ profile and associated geochemical variations in P, Al, Si, and $\sum$REE across the Cambrian–Ordovician GSSP in western Newfoundland, Canada

Results

The $\delta^{13}C_{carb}$ and $\delta^{18}O$ values of well-preserved micrite microsamples range from -4.7 to $+1.7$ ‰ (VPDB) and from -8.7 to -5.5 ‰ (VPDB), respectively; they exhibit very insignificant correlation ($R^2 = 0.00002$) despite the considerable correlation between $\delta^{18}O$ and Mn/Sr ($R^2 = 0.35$). Similarly, the $\delta^{13}C$ and Mn/Sr values show almost no correlation ($R^2 = 0.00004$). Despite the strong correlation between the $\sum$REE and $\delta^{18}O$ values ($R^2 = 0.36$), they exhibit insignificant diagenetic alteration with their $\delta^{13}C$ counterparts ($R^2 = 0.05$). This suggests that the analysed carbonates with their near-primary $\delta^{13}C$ signatures can be utilized to reconstruct a reliable C isotope profile at the Green Point GSSP for global high-resolution chemostratigraphic correlations.

Chemostratigraphic Pattern

The $\delta^{13}C_{carb}$ profile of the studied boundary section reveals a composite of three peaks with a negative shift of $\sim$6.0 ‰, which starts at the base of the Broom Point Member. The negative $\delta^{13}C_{carb}$ shift is preceded by a significant input of P

(3000–9000 ppm) and mild increases of Al (1100–1800 ppm) and Si (2200–4000 ppm) that reflect a significant eustatic drop in sea level. This is consistent with the high total REE contents ($\sum$REE = 150–270 ppm) observed immediately before the C-shift, and with the change from relatively shale-dominated lithology of the Martin Point Member to a more carbonate-dominated in the Broom Point Member. Th/U ratios are invariably constant at about <2 (suggesting reducing conditions) and thus indicate no significant change in redox conditions throughout the formation.

Conclusions

The carbon isotope curve constrains the position of the golden spike at the Cambrian–Ordovician System boundary at the GSSP section, with a position just ahead of a prominent positive excursion within the *Cordylodus intermedius* conodont Zone. The detailed $\delta^{13}C_{carb}$ carbon isotope stratigraphic profile from the uppermost Cambrian to lowermost Ordovician strata in the Green Point section also permits precise matching to global sections with $\delta^{13}C_{carb}$ isotope information covering the same stratigraphic interval.

References

Azmy, K., Stouge, S., Christiansen, J. L., Harper, D. A. T., Knight, I., & Boyce, D. (2010). Carbon isotope stratigraphy of the lower ordovician succession in northeast greenland: implications for correlations with St. George group in western Newfoundland (Canada) and beyond. *Sedimentary Geology, 225*, 67–81.

Azmy, K., Brand, U., Sylvester, P., Gleeson, S., Logan, A., & Bitner, M. A. (2011). Biogenic low–Mg calcite (brachiopods): Proxy of seawater–REE composition, natural processes and diagenetic alteration. *Chemical Geology, 280*, 180–190.

Barnes, C. R. (1988). The proposed cambrian-ordovician global boundary stratotype and point (GSSP) in western Newfoundland. *Canada Geological Magazine, 125*(4), 381–414.

Cooper, R. A., Nowlan, G. S., & Williams, S. H. (2001). Global stratotype section and point for base of the ordovician system. *Episodes, 24*, 19–28.

Erdtmann, B. D. (1988). The earliest ordovician nematophorid graptolites: taxonomy and correlation. *Geological Magazine, 125*, 327–348.

James, N. P., & Stevens, R. K. (1986). Stratigraphy and correlation of the cambro-ordovician cow head group, western Newfoundland. *Geological Survey of Canada, Bulletin, 366*, 1–143.

Terfelt, F., Bagnoli, G., & Stouge, S. (2012). Re-evaluation of the conodont *Iapetognathus* and implications for the base of the Ordovician System GSSP. *Lethaia, 45*, 227–237.