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Original article

Proposed GSSP for the base of Cambrian Stage 10 at the lowest occurrence of *Eoconodontus notchpeakensis* in the House Range, Utah, USA

Proposition de la première apparition de Eoconodontus notchpeakensis *dans le House Range, Utah, États-Unis, comme Point Stratotypique Mondial de la base de l'Étage 10 du Cambrien*

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ABSTRACT

The lowest occurrence of the conodont *Eoconodontus notchpeakensis* (Miller, 1969) has been proposed as the base of Cambrian Stage 10. The horizon is recognized in three sections in the House Range, western Utah, USA in the lower part of the Red Tops Member of the Notch Peak Formation. This horizon fits within a tightly integrated framework that includes conodont, trilobite, and brachiopod biozonations, as well as carbon-isotope stratigraphy and sequence stratigraphy. The proposed horizon is the base of the *Eoconodontus* conodont Zone. This horizon is in the lower part of the *Saukiella junia* Subzone of the *Saukia* trilobite Zone and is near the top of the *Billingsella* brachiopod Zone. The HERB Event is a high-amplitude, negative carbon-isotope excursion that has been identified in Laurentia, Australia, China, and Argentina. The start of the excursion is at a negative carbon-isotope peak that is less than half a metre above the base of the *E. notchpeakensis* Subzone, and the highest-amplitude peak of the HERB Event is near the middle of that relatively thin subzone. The HERB Event has been identified in strata with minimal faunal data, providing the possibility of identifying the base of Stage 10 in nearly unfossiliferous strata. The Notch Peak Formation has been divided into a detailed sequence-stratigraphic framework within a lithostratigraphic context, and some of the sequence boundaries have been identified in Australia and China. Conodonts diagnostic of the *Eoconodontus* Zone have been identified at 54 localities around the world, including in a succession of Cambrian deep-ocean radiolarian cherts. The Utah conodont zonation has been identified across Laurentia and in other parts of the world in facies ranging from continental slope to nearshore sandstone deposits. The variety of correlation tools and the integration of diverse data produce a superior framework for correlation of the proposed base of Stage 10 and for correlation of many horizons within Stage 10.

Mots clés :
Étage 10 du Cambrien
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RÉSUMÉ

La première apparition du conodonte *Eoconodontus notchpeakensis* (Miller, 1969) a été proposée comme base de l'Étage 10 du Cambrien. Cet horizon est reconnu dans trois sections du House Range, dans l'ouest de l'Utah, aux États-Unis, dans la partie inférieure du Membre Red Tops de la Formation du Notch Peak. Cet horizon est intégré avec précision dans un cadre qui comprend des biozonations à conodontes, trilobites,

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et brachiopodes, ainsi que de la stratigraphie isotopique du carbone. L'horizon proposé est la base de la sous-zone à *Eoconodontus notchpeakensis* de la zone à conodontes *Eoconodontus*. Cet horizon se trouve dans la partie inférieure de la sous-zone à *Saukiella junia* de la zone à trilobites *Saukia*, et se situe près de la limite supérieure de la zone à brachiopodes *Billingsella*. L'événement HERB est une excursion négative des isotopes du carbone de grande amplitude qui a été identifiée en Laurentia, en Australie, en Chine, et en Argentine. La base de l'excursion correspond à un pic négatif des isotopes du carbone qui se situe moins d'un demi-mètre au-dessus de la base de la sous-zone à *E. notchpeakensis*, et le pic d'amplitude maximale de l'événement HERB est enregistré au milieu de cette sous-zone relativement peu épaisse. L'événement HERB a été identifié dans des strates pauvres en faune, ce qui offre la possibilité d'identifier la base de l'Étage 10 dans des strates quasi non fossilifères. La Formation du Notch Peak a été divisée selon un cadre stratigraphique séquentiel détaillé dont certaines limites de séquence sont identifiées en Australie et en Chine. Des conodontes indicatifs de la Zone à *Eoconodontus* ont été identifiés dans 54 localités du monde entier, y compris dans une série de cherts à radiolarite cambriens déposés en domaine océanique profond. La zonation à conodontes de l'Utah a été identifiée à travers le Laurentia ainsi que dans d'autres parties du monde dans des faciès variés, allant des dépôts de talus continental à des grès de plateforme interne. La variété d'outils de corrélation et l'intégration de données diverses fournissent un cadre de corrélation remarquable de la base proposée de l'Étage 10 ainsi que de plusieurs horizons de l'Étage 10.

1. Introduction

The various subcommissions of the International Commission on Stratigraphy have finished subdividing and defining boundaries between Eras and Systems of the Geological Time Scale. Recently, these subcommissions have shifted their work to dividing the various Systems into international series and stages. The International Subcommission on Cambrian Stratigraphy has divided the Cambrian System into four series and ten stages. The lower two series each have two stages, and the upper two series each have three stages. Stage 10 will be the highest stage of the highest Cambrian Furongian Series.

Two horizons have been proposed for the base of Stage 10. The lower horizon is at the First Appearance Datum (FAD) of the agnostoid arthropod *Lotagnostus americanus* (Billings, 1860). Peng et al. (2014) proposed placing the Global Boundary Stratigraphic Section and Point (GSSP) in the Wa'ergang section in Hunan, South China. Lazarenko et al. (2011) proposed a GSSP at the same level in the Khos-Nelege section in northern Siberia, Russia. Miller et al. (2011) and Landing et al. (2011) proposed placing the GSSP at a somewhat higher stratigraphic level, at the FAD of the euconodont *Eoconodontus notchpeakensis* (Miller, 1969) in the House Range in western Utah, USA.

The HERB Event is a distinctive negative carbon-isotope excursion that has been identified in several continents (Ripperdan et al., 1992; Ripperdan and Miller, 1995; Jing et al., 2008; Kouchinsky et al., 2008; Sial et al., 2008). The base of the HERB Event is less than half a metre above the proposed GSSP, and the peak of the excursion is within the relatively thin *E. notchpeakensis* Subzone. The base of the HERB Event and the negative excursion peak would be useful for identifying and correlating a GSSP based on the conodont horizon. Miller et al. (2011, 2014) identified three sections in western Utah that might serve as a GSSP and presented data on trilobites, brachiopods, carbon-isotopes, and sequence stratigraphy that would further characterize the proposed conodont horizon and increase the potential for its correlation. Each of these correlation tools will be discussed in separate sections of this paper.

2. *E. notchpeakensis* horizon in Utah

Miller et al. (2003) presented detailed range charts for conodonts, trilobites, and brachiopods and also defined sequence-stratigraphic units in several sections in western Utah. That paper also included detailed descriptions of 17 measured sections that are distributed across an area that is approximately 110 km from south to north, from Lawson Cove in the northern Wah Wah Mountains to the northern Drum Mountains in the north (Fig. 1B). Seven of these 17 sections include strata in which the FAD of *E. notchpeakensis* has been identified. The seven sections are located on Fig. 1B; among these, the Steamboat Pass, Lava Dam Five East, and Sneakover Pass sections are the best because of diversity and abundance of data, exposure, and access. Several additional sections are also located on Fig. 1B. Miller et al. (2011) presented range charts for conodonts and trilobites and other data for the Steamboat Pass and Lava Dam Five East sections. New diagrams herein present data from the Sneakover Pass section, which is located more precisely in Fig. 2. This paper is an expanded version of a short paper by Miller et al. (2014), and it has new conodont, trilobite, brachiopod, and carbon-isotope data that were not included in that paper nor in Miller et al. (2011).

3. Stratigraphy and lithology

Miller et al. (2012a) discussed and illustrated Cambrian and Ordovician strata in western Utah, which were deposited on a rapidly subsiding, tropical, passive-margin carbonate platform. Cambrian strata in the House Range are ~3870 m thick, of which ~850 m is assigned to the upper Cambrian Furongian Series. Relevant strata are assigned to the Notch Peak Formation and the House Limestone and include the Hellnmaria, Red Tops, Lava Dam, and Barn Canyon Members (Fig. 3). The proposed base of Cambrian Stage 10 is in the lower part of the Red Tops Member. Stage 10 would continue upward to the base of the *Iapetognathus* Zone, in the middle of the Barn Canyon Member of the House Limestone (Fig. 3).

The Notch Peak Formation is entirely limestone in the Sneakover Pass area, and exposures there comprise the type sections of its three members. The Hellnmaria Member is primarily shallow subtidal lime mudstone with many stromatolitic and thrombolitic intervals. This member is 367 m thick in the area, but only the top 34 m is documented in this paper (Fig. 4). The Red Tops Member (Fig. 5) comprises 44 m of high-energy lime grainstone with a few thin intervals of lime mudstone, all deposited during a sea level lowstand (Red Tops Lowstand on Fig. 3). The Lava Dam Member is 110 m thick and can be divided into three parts. The lower ~40 m is subtidal, thick-bedded, cherty lime mudstone. The middle part comprises ~12.5 m of high-energy lowstand deposits (Lange Ranch Lowstand on Fig. 3) that include lime mudstone, skeletal and ooid grainstone, and a bed of stromatolitic boundstone. A major extinction of conodonts, trilobites, and brachiopods occurs at the base