GEOSPHERE

GEOSPHERE; v. 14, no. 3

doi:10.1130/GES01575.1

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CITATION: Bornhorst, T.J., 2018, Maximum depositional age of the Neoproterozoic Jacobsville Sandstone, Michigan: Implications for the evolution of the Midcontinent Rift: Geosphere, v. 14, no. 3, p. 1380–1381, doi:10.1130/GES01575.1.

Science Editor: Shanaka de Silva

Received 14 June 2017
Accepted 3 August 2017
Published online 29 March 2018

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Maximum depositional age of the Neoproterozoic Jacobsville Sandstone, Michigan: Implications for the evolution of the Midcontinent Rift: COMMENT

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Malone et al. (2016) propose that the maximum age of the Jacobsville Sandstone is 959 ± 19 Ma based on laser ablation U-Pb geochronological data from detrital zircons. This result has been used to draw far-reaching conclusions about the later phase of evolution of the Midcontinent Rift System. However, there are ample reasons to question this conclusion of Malone et al. (2016, herein) with respect to their proposed maximum age of the Jacobsville Sandstone (JS).

The exposed JS is mostly shallow dipping, <10°, except locally in areas of structural disturbance such as in the vicinity of the Keweenaw fault (Kalliokoski, 1982). In the Upper Peninsula of Michigan (figure 3A of Malone et al.), the JS unconformably overlies older Mesoproterozoic to Archean rocks on the eastern and southern edges of the exposed JS basin and is in fault contact with Midcontinent Rift basalts along the Keweenaw fault. The deposition of JS on top of the unconformity cannot be assumed to be synchronous. The age of the JS exposed locally on the unconformity in the L'Anse area may not be the same age as the JS on the unconformity in deeper parts of the JS basin such as between L'Anse and the Keweenaw fault (figure 3A of Malone et al.). The general shallow dip in areas of exposed JS could be indicative of the dip in the entire vertical stratigraphic section as can be inferred from a seismic-reflection profile of Cannon et al. (1989, their figure 4). In this case, the beds exposed at the unconformity are stratigraphically of about the same age as JS exposed at the surface elsewhere. In the depositional basin to the east of the Keweenaw fault (figure 3A of Malone et al.), the present-day thickness of the JS exceeds 1100 m in drill core and may be as thick as 3000 m near the Keweenaw fault as estimated from geophysical data (Kalliokoski, 1982). Hedgman (1992; cited by Malone et al.) and Bowers (1989) studied a number of long JS drill cores and documented that the uppermost 125 m are lithologically similar to surface exposures but that stratigraphically older JS rocks are lithologically different. Hence, the JS is not a homogeneous unit resulting from a single depositional event. The assumption by Malone et al. that all of the JS has a maximum age of less than or equal to ca. 960 Ma based on their sampling of only surface exposures is questionable because a significant thickness of shallow-dipping, lithologically distinct JS lies below the surface.

An alternate interpretation is that the age of the JS ranges from less than or equal to ca. 960 Ma (from Malone et al.) to an age represented by the top of the underlying Oronto Group, although the time gap of the unconformity is unknown. Cannon (1992) estimated the upper age of the Freda Formation, the uppermost formation within the Oronto Group, to be ca. 1060–1040 Ma. The age of the base of the Nonesuch Formation, which underlies the Freda Formation, is 1081 ± 9 (Ohr, 1993). An older age range for much of the JS sedimentation than proposed by Malone et al. is compatible with existing hypotheses on the evolution of the Midcontinent Rift.

Table 1 of Malone et al. provides U-Pb geochronological data for the youngest 20 detrital grains out of the 2050 examined in their study. They rely on the youngest four critical zircon grains, or 0.2% of the total data set, to draw their conclusion on the maximum age of the JS. The age dates from these four critical zircon grains should be considered as anomalous until they are proven to be trusted as valid. In their Reply, I hope the authors will include the quality assurance and quality control for mineral separation to insure that the four critical zircon grains were not the result of contamination in the equipment. In addition to the standard analytical measurement issues, the validity of apparent ages reported in table 1 of Malone et al. relies upon the assumption that the analytical results are geologically meaningful. It is well known that the large analytical volume created by laser ablation (Malone et al. used a spot diameter 20 microns wide) to date complex zircon grains may be subject to uncertainty because the analytical volume can include parts of zircon grains formed at different times such as from recrystallization or overgrowths or parts affected by Pb-loss (e.g., Kröner et al., 2014, and references therein). For results to be trusted, researchers using this method must demonstrate that only synchronous zircon was in the analytical volume and must provide petrographic evidence that selected grains were appropriate candidates for laser ablation. Neither of these requirements were met for the four critical zircons (or any zircons) used by Malone et al. For example, cathodoluminescence is not mentioned in the Methodology section, even though such methods can reveal complex zircon grains, and there are no high magnification or energy-dispersive scanning electron microscope images. More convincing evidence for the apparent ages of the four critical grains could have been provided by showing images of the zircons or dating of carefully selected areas using a higher precision method with a small analytical volume, such as sensitive high-resolution ion microprobe.

A simple review of the best apparent ages presented by Malone et al. in table 1 also illustrates the uncertainty of their conclusions. Two of the four critical zircon grains have very large 1-sigma measurement errors of ±52.6 and 60.8 Ma. Such large errors suggest that these zircon grains are complex and/or significantly discordant. The other two zircons have 1-sigma measurement errors of ~±29 Ma. Additional zircon ages with large errors among the 20 youngest zircon grains reported in table 1 by Malone et al. make this reader doubt that these results can be trusted as geologically meaningful ages. Malone et al.'s figure 4b shows the overlap in the apparent ages for the four critical zircon grains based on their reported 1-sigma measurement errors (1-sigma bars are shown—not 2-sigma bars as stated in the figure itself). Malone et al. calculate an age from these four different zircon grains of 959 Ma ± 19 Ma, even though there is no demonstrated connection among the zircons, such as being from the same potential source. This age is questionable. Further, the statistics apparently used to justify an error of ±19 Ma by averaging four unrelated apparent ages with 1-sigma measurement errors of ±29.0, ±29.7, ±52.6, and ±60.8 Ma are not described in detail and, thus, are questionable. The 1-sigma measurement error for the single youngest zircon grain of these four critical zircon grains not only overlaps with the other three critical grains (as shown in figure 4b) but, in fact, also overlaps with ten other zircon grains out of their reported 20 youngest grains (table 1 of Malone et al.). In other words, there are 14 zircon grains (four critical and ten others apparently not deemed critical out of 20) that are not distinguishable from one another. Only the four zircons with the youngest ages, however, were selected to estimate the maximum age of the JS. In addition, all of the youngest 20 apparent zircon ages reported in table 1 of Malone et al. overlap with two or more of the four critical zircon grains, and they are therefore indistinguishable from those four critical zircon grains used to determine a maximum age of the JS. Thus, there is ample reason to question the conclusion by Malone et al. of a 959 ± 19 Ma maximum age of the JS based solely on these four critical zircon grains. An alternate interpretation of these apparent ages is that surface exposures of the Jacobsville Sandstone are less than or equal to between 1093.6–925.1 Ma, which represents the maximum age range of the 20 apparent ages (±1-sigma measurement error).

This reader asserts that the maximum age of the JS as presented by Malone et al. is questionable. The use of the word "Neoproterozoic" in the title of the paper incorrectly implies certainty rather than the actual uncertainty. Given the questions and uncertainties regarding the data, the resulting interpretations presented by Malone et al. for the late-stage evolution of the Midcontinent Rift are speculative.

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