Chemie der Erde 72 (2012) 77–84

Contents lists available at ScienceDirect

Chemie der Erde

journal homepage: www.elsevier.de/chemer

Another sea area separated from the Panthalassic Ocean in the Norian, the Late Triassic: The lowest Sr isotopic composition of the Ishimaki limestone in central Japan

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ARTICLE INFO

Article history:
Received 4 March 2011
Accepted 13 June 2011

Keywords:
Sr isotopic composition
Seamount-type limestone
Late Triassic
Norian
Paleoceanic topography
Norian conodont
Seawater $^{87}Sr/^{86}Sr$ ratio
Hydrothermal fluids

ABSTRACT

Mt. Ishimaki is the Jurassic accretionary complex of the Chichibu Belt in Toyohashi City, near Nagoya in central Japan. The Ishimaki limestone is thought to be seamount-type limestone. The P_1 elements of the conodonts *Norigondolella navicula* and *Ancyrogondolella quadrata* found in the limestone indicate it is of Norian age. The Sr isotopic compositions of 45 Ishimaki limestone samples ranged from 0.7055 to 0.7077. Eighteen of these samples had lower Sr isotopic compositions than the lowest Sr isotopic composition (0.7068) of seawater throughout the Phanerozoic. The Sr isotopic compositions in the limestone block are generally lower at the base of the block and higher at the top. The present Sr isotopic compositions of the Ishimaki limestone are unlikely to have been reduced by post-depositional alteration because most of the limestone samples had a low amount of Mn (<300 ppm) or high Sr/Mn ratios (>2) and the conodont elements had low (1–2) CAI (conodont alteration index) values. Additionally, there was little acid-insoluble residue. Thus, the low Sr isotopic compositions are thought to represent the strontium of the past ambient seawater. The low Sr isotopic compositions are in complete disagreement with the generally recognised range of seawater Sr isotopic compositions in the Norian stage of the Late Triassic (0.7075–0.7078) because the depositional environment of the Ishimaki limestone was closed or semi-closed from the Panthalassic Ocean. Therefore, the Sr isotopic composition of the limestone differs from that of the Panthalassic seawater. The low Sr isotopic compositions were probably affected by Sr inflows from mafic oceanic crust by hydrothermal fluid circulation or from hinterlands surrounded by mafic rocks by river water circulation.

1. Introduction

The Sr isotopic compositions ($^{87}Sr/^{86}Sr$) of seawater are generally homogeneous throughout the ocean (Faure et al., 1965; Hamilton, 1966; Murthy and Beiser, 1968), and little isotopic fractionation from seawater to marine biogenic carbonates occurs. The Sr isotopic compositions of marine biogenic carbonates are identical to those of the seawater at the time of deposition if they have not been modified by later alteration (Ito, 1993). Attempts to associate Sr isotopic compositions of past seawater with marine biogenic carbonates have been conducted by Peterman et al. (1970), Veizer and Compston (1974) and others. Burke et al. (1982) summarised the general trends of the variation curve of $^{87}Sr/^{86}Sr$ ratios in Phanerozoic seawater. Sr isotope stratigraphy using this variation curve to determine the age of marine biogenic carbonates has become an effective method for determining the ages of rocks without index fossils (Elderfield, 1986). Recently, the Sr isotopic composition of past marine carbonates has been regarded as a proxy method for global chemostratigraphy, dating and paleoenvironmental analysis (Veizer et al., 1999; Nishioka et al., 1991; Miura et al., 2004; McArthur and Howarth, 2004; Kani et al., 2008).

Mt. Ishimaki, with a peak elevation of 358 m, is a geological block in the Jurassic accretionary complex of the Chichibu Belt in Toyohashi City, near Nagoya in central Japan (Hori, 2008) (Fig. 1). The Ishimaki limestone is thought to be a seamount-type limestone because it is associated with greenstone and chert. The deposition age of the limestone has not been clarified because no index fossils have been found within it (Hori, 2008). Suzuki et al. (2009) recently found P_1 elements of *Norigondolella navicula* (Huckriede, 1958) and *Ancyrogondolella quadrata* (Orchard, 1991) from the Ishimaki limestone, and these conodonts indicate that the limestone is from the Early Norian within the Late Triassic.

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doi:10.1016/j.chemer.2011.06.004

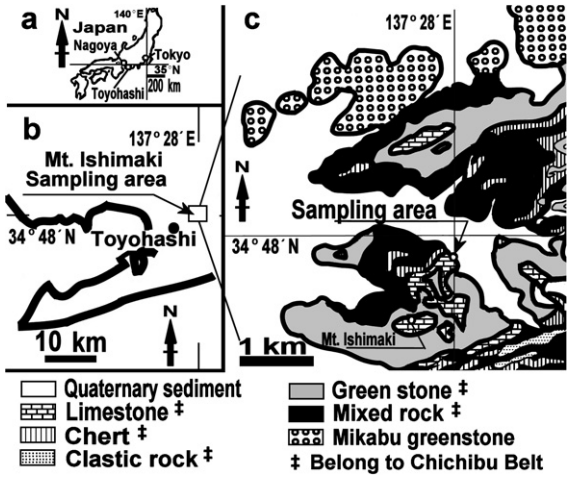

Fig. 1. (a and b) An index map and (c) a simplified geological map of the area surrounding Mt. Ishimaki. The geological map was modified from Niwa (2004).

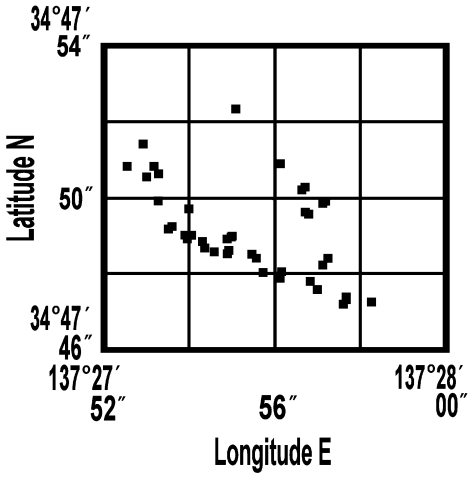

Fig. 3. Sampling points in the Ishimaki limestone block with east longitude vs. north latitude.

The distribution of Sr isotopic compositions in the 200-m wide and 60-m thick Ishimaki limestone block was investigated in this study. Extremely low Sr isotopic compositions were found. The aim of this study is to clarify why the Ishimaki limestone block, which was deposited by seawater during the Norian, had the lowest Sr isotopic composition throughout the Phanerozoic.

2. Geological setting of the Ishimaki limestone and sampling points

The study area is located in Toyohashi City, southeast of Nagoya City in central Japan. The geological units of the Chichibu Belt are distributed in a belt shape from east to west. The Jurassic accretionary complex of the Chichibu Belt contacts Sambagawa metamorphic rock (Mikabu greenstone in Fig. 1(c)) along a high angle fault at the northern edge and is widely overlain by Quaternary sediments (Hori, 2008). The lower part of Mt. Ishimaki mainly consists of blocks of mixed rock and greenstone, but greenstone, limestone and chert are tectonically distributed in the upper part (Fig. 1(c)). The greenstone primarily consists of basaltic lava and tuff. The greyish to white limestone is mainly layered, massive and partly recrystallised. The greenstone is partly intercalated into the limestone (Niwa, 2004).

The limestone samples for the Sr isotope analysis were collected from a lens-shaped block (Fig. 2) approximately 200 m wide in both the latitude and longitude directions and approximately 60 m in the vertical direction on the northern slope of Mt. Ishimaki (Fig. 1). This block is surrounded by mixed rock and greenstone. Forty-five limestone samples were collected from this block in vertical and horizontal succession. Samples from the recrystallised part of the block were not collected. The latitude and longitude of each sampling point were accurately determined using a GPS receiver (Fig. 3). The locations of the sampling points are listed in Table 1.

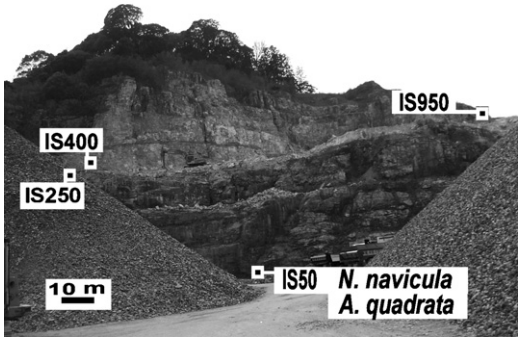

Fig. 2. Image of the Ishimaki limestone block. The thickness and width of the block are approximately 60 m and 200 m, respectively. Forty-five Ishimaki limestone samples were collected from the block. Two species of conodont elements were extracted from the IS50 site. Several fragmented pieces of conodonts were also extracted from the IS250, IS400 and IS950 sites.

3. Age and thermal history of the Ishimaki limestone block

Two species of conodonts were collected from the IS50 point (Fig. 2 and Table 1) (Suzuki et al., 2009): *N. navicula* (Huckriede,

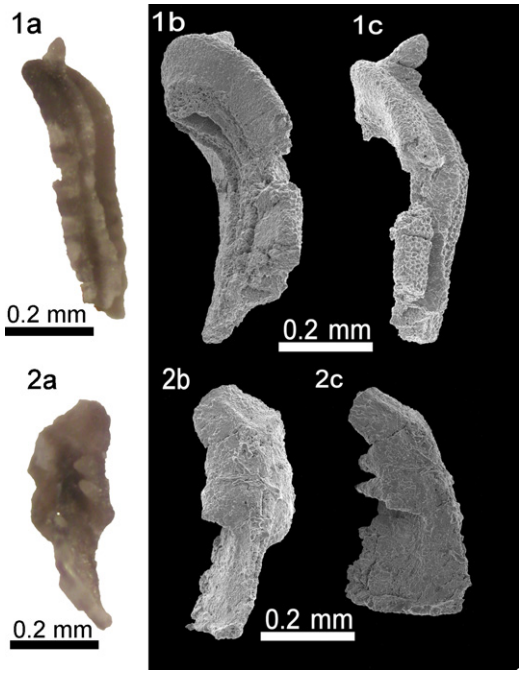

Fig. 4. Two species of Norian conodonts at IS50. Upper: *Norigondolella navicula* (Huckriede) extracted from the IS50 sample. 1a is a binocular micrograph. 1b and 1c are SEM micrographs. 1a is an oblique upper view. This CAI value is 1.0–2.0. 1b, oblique lower view. 1c, lateral view. Lower: *Ancyrogondolella quadrata* (Orchard) extracted from the IS50 sample. 2a is a binocular micrograph. 2b and 2c are SEM micrographs. 2a, upper view. This CAI value is 1.0–2.0. 2b, lower view. 2c, lateral view.