

Saline giants, cold cradles and global playgrounds of Neoproterozoic Earth: the origin of the Animalia

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Abstract: It is still an enigma of just what triggered the development of multicellular animals, the metazoans. The rise of oxygen has commonly been suggested as the cause, which probably had a marked effect. But why do the metazoans seem to appear in the fossil record, with some diversity, in the late Neoproterozoic around 575–580 million years ago? Perhaps the sudden appearance is related to a rapid expansion of metazoans into global oceans as they became markedly less saline with the deposit of saline giants in the Neoproterozoic. Metazoans may well have developed first in ‘cold cradles’ in deltaic and estuarine conditions earlier, when seas were more saline, and with the removal of salts from the global oceans, the seas became their ‘global playgrounds’ and with this invasion the fossil record improved significantly. Such an idea can only be tested with more precise dating of the saline giants themselves.

For much of Earth history, beginning around 2.5 billion years ago, the planet has had a rather mild climate, despite its rather ‘toasty’ beginnings and its current glacial leanings. Thus, the rule of thumb that palaeontologists use in interpreting the past, uniformitarianism (the present is the key to the past), may not always be appropriate. However, during one period of time, from around 700 million to at least 580 million, perhaps it is appropriate—or is it? This was a period of numerous glacial events, some of which were global, and likely much more severe than the glacials of the past two million years on Earth, the Pleistocene. Such severely cold conditions, even at the Equator, and the variability of climate, from cold to warm and back to cold again over more than 180 million years, was the time in Earth history when the first undoubted metazoans appear in the fossil record. They first appear as tiny embryos and adults recorded in China (Xiao *et al.* 1998; Li 2006) and somewhat later as macrofossils known from many places around the globe, most notably from Newfoundland, Australia, Russia and Namibia.

What was so special about this time which fostered such advances in complexity—leading from a world dominated by microbes to one resplendent in complex, often mobile, macro-animals and eventually shelled and skeletonized forms that begin to appear in the latest Neoproterozoic (*Cloudina*)? ‘Weedy environments’ are often sites of innovation—those environments that are new and variable. Neoproterozoic environments were certainly such weedy places—variable in salinity, oxygen

content, temperature and likely saturation of certain minerals needed for construction of hard parts. Knauth (2005) has noted that ocean water salinity could have played an important role in controlling accessibility to global oceans for complex metazoan metabolism. Lower salinity itself favoured metazoan metabolism and also enhanced oxygen saturation. Add to that colder temperature during glacial events, which would have enhanced oxygen concentrations further, and global oceans would have been most inviting to the expansion of metazoans. These metazoans may well have developed elsewhere than in the global hypersaline oceans (perhaps as high as 1.6 to 2 times modern salinities (Land 1995; Knauth 1998, 2005)), prior to massive halite deposition in the late Neoproterozoic and early Phanerozoic, which changed the world’s seas profoundly. Major salt deposition (reflected by ‘saline giants’) is known to have occurred on Earth only a few times in its history, two of those occurring between 500 and 700 million years, with major deposits preserved today in Australia, Oman, Saudi Arabia, Iran and Pakistan. These signal the sequestering of halite on the growing continents, thus significantly lowering salinity in the global oceans. Knauth (2005) has suggested that metazoans might have developed first in fresh waters because of their lower salinity (which would have been accompanied by higher oxygen saturation) during times when the global oceans were too saturated with salts to favour a metazoan presence. Fedonkin (1996) noted that metazoans might have developed in ‘cold cradles’ during the lowered temperatures

of the Neoproterozoic glaciations. This could have happened before the Neoproterozoic glacials in cold, freshwater cradles, or in deltaic areas where inflowing fresh waters lowered the salinity of the open ocean, and in places where lowered temperatures also enhanced oxygen solubility. Then, with deposition of the 'salt giants' on the growing continents, the floodgates to global oceans may have been opened as salinity dropped, oxygen saturation escalated first in the cold oceanic 'playgrounds' that would have been widespread during Neoproterozoic glacial times. Within 4 million years of the meltdown of the final glacial events, the Gaskiers Glaciation dated at around 582 million years (Halverson *et al.* 2005; Bowring & Condon pers. comm., 2006), fully developed, complex metazoans were present. The degree of complexity of these organisms, despite the uncertainty of their relationships with crown groups of today, combined with the data provided by molecular studies (e.g. Blair & Hedges 2004; Hedges *et al.* 2004), in spite of lack of agreement on dates, clearly indicate that complex metazoans were present *before* this date.

Where might one look for the older fossils of the Ediacarans? As mentioned above, Knauth (2005) has echoed a suggestion made before that perhaps metazoans were living in environments not frequently preserved, such as freshwater lakes and rivers—sediments of which need intensive investigation in the future. Such non-salty environments would certainly have provided a more 'inviting' abode for most metazoans and with or without the cold, a place with more oxygen needed to fuel metazoan metabolism. Despite the oceans of the Phanerozoic, including those of today, being ideal environments for the most diverse metazoan communities, this may not have been the case in the Neoproterozoic. Knauth further suggests that the acquisition of shells in the Early and Middle Cambrian may have been the result of changing ocean saturation in calcite, silica and phosphate. Perhaps also related to changing salinity is the erosion of continental shelf sediments exposed during lowered glacial sea levels or even erosion of a lengthy mountain chain in the early Phanerozoic brought about by plate tectonics. Degradation of these highlands would not only have introduced nutrients and new environments (Brasier & Lindsay 2001; Squire *et al.* 2006) but also would have supersaturated the global oceans with the building blocks of hard parts.

And where did the Ediacarans go? Some clearly were stem groups that have relationships to crown groups—*Kimberella* to the Mollusca, as an example. Others may simply have disappeared because their way of life came to an end. With the demise of the vast microbial mats, which so characterized the Neoproterozoic and before, the 'jobs' of

such organisms as *Yorgia* and *Dickinsonia* came to an end. These likely vacuum cleaners or 'cleaning sponges', which may well have absorbed their way into the microbial mats as a way of 'feeding', then moved on to the next 'delicious' spot leaving their long-lasting absorption patterns behind, may simply have run out of food widespread enough to maintain their lifestyle. Just what brought about the demise of the microbial mats and the beginning of deep burrowing and bioturbation, which disrupted these mats forever, may simply have been a change in ocean chemistry and the development of more efficient feeding styles, greater mobility of the newly evolved organisms, including their ability to burrow, at first shallowly and then deeper—forever changing the sea floors of global oceans.

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