

<p>Institution: University of Oxford</p>
<p>Unit of Assessment: UoA7 (Earth Systems and Environmental Sciences)</p>
<p>Title of case study: UoA7-5: UNESCO World Natural Heritage status for the Chengjiang (Cambrian) fossil site, Yunnan Province, China</p>
<p>1. Summary of the impact</p> <p>Research carried out at Oxford University has helped demonstrate the extraordinary significance of a fossil site in Yunnan Province (China) for understanding evolution at the time of the Cambrian explosion. This research contributed to the site being proposed and, in 2012, designated as a UNESCO World Heritage site. An Oxford University researcher (Siveter) played an important part in this process, drawing on his research when writing the World-Heritage bid. Government policy for the Chengjiang area has now shifted away from phosphate mining to conservation, education and tourism, with the establishment of a Geopark and, in 2010, a Museum. Annual visitor numbers to the area are rising, already in the thousands, benefiting the regional economy. The Chengjiang site has been preserved for future generations to investigate and enjoy.</p>
<p>2. Underpinning research</p> <p>Of the tens of thousands of sites throughout the world that yield fossils, just a few of them yield fossils that are preserved with not only their hard parts, but also with their soft parts. Such sites of exceptional preservation - fossil Lagerstätten - provide far more information about the palaeobiology, evolution, and history of life on Earth than do typical fossil sites. Even fewer of these fossil Lagerstätten happen to represent a time of major faunal and/or floral change. One site that fulfills all these rare criteria is the Chengjiang (Cambrian) Lagerstätte in Yunnan Province, China.</p> <p>The lower Cambrian fossils of Chengjiang represent one of the world's most important fossil assemblages. This ≈525-million-year-old marine fauna is contributing fundamentally to our understanding of one of the most important periods in the history of life on Earth, the Cambrian 'explosion'. This event heralded the first appearance in the fossil record of most of the major animal groups that comprise global present-day marine biodiversity. Especially noteworthy amongst the Chengjiang fauna is the earliest vertebrate. The fauna also provides representation of early animal body plans, and as a whole indicates the earliest, most complete, animal community. Over 200 species ranging across 16 phyla have been recognized since discovery of the fauna in 1984. They occupy, even at this relatively early geological time, most major marine ecological niches, and represent a wide range of feeding types, indicating an elaborate ecosystem. The majority of the species are known only from the Chengjiang biota.</p> <p>Important research on the Chengjiang Lagerstätte has been conducted by Professor Derek Siveter at Oxford University's Department of Earth Sciences and Museum of Natural History. He has formed part of a small team of UK palaeobiologists (with two other scientists from Leicester University) who have researched the Chengjiang biota together with the discoverer of the Lagerstätte, Professor Hou Xianguang (Director of the Yunnan Key Laboratory for Palaeobiology, Yunnan University, Kunming, China).</p> <p>This research has resulted in a series of high-profile publications in peer-reviewed journals. These publications have added to the fossil database and outlined the evolutionary and ecological significance of various parts of the Chengjiang fauna. They include an investigation of the morphology and phylogenetic position of the earliest vertebrates (Hou et al. 2002 [1]) and the description of soft-part morphology and affinity of bivalve (bradoriid) crustaceans (Hou et al. 2010 [3]). They also identified very early collective behaviour in arthropods (Hou et al. 2008, 2009 [4-5]) and reported the discovery of an important early-Cambrian hemichordate zooid (Hou et al. 2011 [6]).</p> <p>Siveter's research also contributed to a book, which he coauthored; "The Cambrian fossils of Chengjiang, China" (Hou et al. 2004 [2]) published by Blackwells Scientific. This book presents a</p>

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wide range of research and illustration providing full details of the fauna and flora of Chengjiang. It has received more than 200 citations in the research literature, and a second edition is now in preparation.

The detailed paleontological research conducted on the Chengjiang Lagerstätte has provided important advances in our knowledge of the evolution of life at the time of the Cambrian explosion, and has firmly outlined the critical significance of the Chengjiang biota.

3. References to the research

The three asterisked outputs best indicate the quality of the underpinning research.

1. Hou, X., Aldridge, R.J., Siveter, David J., Siveter, Derek J. & Feng, X. 2002. New evidence on the morphology and phylogeny of the earliest vertebrates. *Proceedings of the Royal Society of London B*, **269**, 1865-1869.
(<http://rspb.royalsocietypublishing.org/content/269/1503/1865.short>)
2. * Hou, X-G, Aldridge, R.J., Bergström, J., Siveter, David J., Siveter, Derek J. & Feng, X-H. 2004. *The Cambrian fossils of Chengjiang, China. The flowering of early animal life.* 233 pp, Blackwell, Oxford.
This book was the first to comprehensively document the Chengjiang biota in the English language, including a comprehensive reference list of the associated, significant, research papers, many of which were published in Chinese journals. It has attracted over 200 citations in the research literature.
3. Hou X-G., Williams, M., Siveter, David J., Siveter, Derek J. & Richard J. Aldridge & Robert S. Sansom. 2010. Soft-part anatomy of the Early Cambrian bivalved arthropods *Kunyangella* and *Kunmingella*: significance for the phylogenetic relationships of Bradoriida. *Proceedings of the Royal Society of London B*, **277**, 1835-1841, doi:10.1098/rspb.2009.2194.
4. * Hou, X-G., Siveter, Derek J., Aldridge, R.J. & Siveter, David J. 2008. Collective behaviour in an Early Cambrian arthropod. *Science*, **322**, 224.
Unique, chain-like associations of specimens of a new arthropod from the Chengjiang Lagerstätte, provides evidence that sophisticated collective behaviour of animals was present some 525 million years ago in the early Cambrian, coincident with the earliest extensive diversification of multi-cellular life, the so-called Cambrian explosion event.
5. Hou, X-G., Siveter, Derek J., Aldridge, R.J. & Siveter, David J. 2009. A new arthropod in chain-like associations from the Chengjiang Lagerstätte (Lower Cambrian), Yunnan, China. *Palaeontology*, **52**, 951-961.
6. * Hou, X-G., Aldridge, R.J., Siveter, David J., Siveter, Derek J., Williams, M., Zalasiewicz, J. and Ma, Xiao-ya. 2011. An early Cambrian hemichordate zooid. *Current Biology*, **21**, 612-616.
A new, exceptionally preserved fossil from the lower Cambrian of Chengjiang represents by far the best-preserved, the earliest, and the largest hemichordate zooid from the fossil record. It provides new insights into the soft-tissue morphology and evolution of the group, demonstrating stasis in pterobranch morphology, mode of coenecium construction, and probable feeding mechanism over 525 million years.

4. Details of the impact

The impact of this research has been in public communication of science, and in protection of the environment. In particular, the research contributed to the designation of the Chengjiang fossil site as a protected UNESCO World Heritage Site in 2012.

The 2004 book on the Chengjiang Biota (Hou et al. [2]) was an important publication, flagging the significance of the Chengjiang site internationally to a wide ranging readership. In the same year, Chinese Premier Wen Jiabao issued instructions to “*protect the Chengjiang biota as a world treasure and natural heritage of significant scientific value*” [9] and the idea of submitting the

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Chengjiang fossil site for world heritage status was first considered. In 2010, Gao Jinsong the Mayor of Yuxi City, suggested that the central government support the nomination of the Chengjiang biota for inclusion in the Chinese list of World Heritage nominations; a suggestion subsequently supported by Wen Jiabao. In 2011, Jiang Weixin, Chinese Minister of Housing and Urban-Rural Development, nominated the Chengjiang Fossil Site to UNESCO for World Heritage status with bid papers that included those that Derek Siveter had played a significant part in writing.

Siveter was invited in 2010 by the Yuxi City Government to act as one of three official scientific external consultants to help write a World-Heritage bid for the Chengjiang fossil-site [7]. He had specific responsibility for drafting parts of the bid, including descriptions, illustrations and statements of significance for all the major groups of Chengjiang fossils; work that relied heavily on his previous knowledge and research [e.g. 1-6]. He also helped draft the scientific rationale of the bid [7]. In addition to writing parts of the bid, Siveter provided advice to Chinese colleagues during its progress, enabling them to address questions from UNESCO during the bid's scientific and field assessment. On 1st July 2012 the bid proved successful, and the site was admitted to the World Heritage list at the UNESCO Ratification Meeting in St Petersburg [10]. This success gave China its first palaeontologically based World Heritage site.

World Heritage is the designation for places on Earth that are of outstanding universal value to humanity and as such, have been inscribed on the World Heritage List to be protected for future generations to appreciate and enjoy. UNESCO states of the Chengjiang site that it “...presents an exceptional record of the rapid diversification of life on Earth during the early Cambrian period, 530 million years before present. In this geologically short interval almost all major groups of animals had their origins. The property is a globally outstanding example of a major stage in the history of life, representing a palaeobiological window of great significance” [10].

World Heritage status has benefitted the Chengjiang region. As it was being put forward for such status, the Chengjiang site was established as a Geopark, leading to some 3,000-5,000 people visiting the Chengjiang site in 2009, including those from around China and overseas. UNESCO projects that World Heritage status will lead to an increase of annual visitors to 40,000 in the next five years [10], and a new museum has been built within the World Heritage Site, opening in 2010. In a province where tobacco production and mining offer the only main industries, the site is diversifying and boosting local and regional economies, with the county town of Chengjiang and the Fuxian Lake Provincial Scenic Area providing accommodation for the increasing number of visitors. Chengjiang County Museum has also established educational outreach activities in Yunnan related to the Chengjiang fossil site. These feature a series of publications for popular science education, including “*Chengjiang Faunal Fossils and Geological Exploration*” and “*Guidelines for the Basic Geology of Chengjiang Faunal Fossils National Geopark*”.

World Heritage status has also protected the environment of the region. Provincial government policy has, since 2009, stopped 14 phosphate mines from operating in the locality, while local government has invested RMB 78 million to protect the natural landscape and to support the Geopark, as well as building a natural history museum. “...the local government will promote tourism based on the fossil site to benefit local people from world heritage” [8,9].

A number of exhibitions and public communication of science activities have been organized in cooperation with domestic and foreign institutes. Exhibitions of Chengjiang fossils and posters have been organized in six countries and regions outside Yunnan. As the prime example, Siveter played a fundamental role in production of a major public exhibition on the Chengjiang biota in the Oxford University Museum of Natural History in 2010. This involved the loan, with appropriate government permission, of some 150 excellent specimens from the Key Laboratory for Palaeobiology, Yunnan University. The exhibition was the first time that Chengjiang material of this quantity and importance has been exhibited outside China. The exhibition was cited in the UNESCO World heritage application to support the bid. The museum was visited by 304,770 people during the period the exhibition was open (17 May – 14 November 2010), giving some indication of numbers who will have witnessed the exhibition.

The broader world community has also benefitted. A key site for our understanding of life on Earth and the roots of biodiversity, including our own vertebrate origins, has been internationally

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recognised as having universal value, and will be managed and protected as a consequence. If the site had not gained such international recognition, it is probable that its paleontological treasures would have been lost to phosphate mining. A truly exceptional scientific resource has been maintained for palaeobiologists, evolutionary biologists, students of the history of life and the general public, to investigate and enjoy.

5. Sources to corroborate the impact

7. Letter of Appointment. From Yuxi City government, in 2010, indicating the scientific consultation role of Prof. Siveter in the Chengjiang fossil site World Heritage bid. [On file].
8. Publicity document. Distributed by Yunnan Provincial government sources, following UNESCO ratification of World Heritage status to the Chengjiang fossil site. Includes comment from the 'People's Daily', the 'Beijing Times', and the website 'www.yunnan.cn'. Corroborates World Heritage site designation, contains quote from Chinese Premier, supports figures on spending and visitor numbers and local government support to developing the area.
9. Honorary Credential award. Presented by Yuxi City Government, 20 May 2013, to D. Siveter, in recognition of his scientific contribution to the Chengjiang fossil site World Heritage bid. [On file].
10. UNESCO web page. <http://whc.unesco.org/en/list/1388>. Indicates the UNESCO listing and significance of the Chengjiang fossil site.
11. Public Lecture. On the Chengjiang biota, to the Hong Kong branch of the Royal Geographical Society, by Professor Derek Siveter. (21 May, 2013). See <http://www.rgshk.org.hk/public/event.php?pageld=54&eventId=545>