Institution: University of Leicester

Unit of Assessment: 7 Earth Systems and Environmental Sciences

Title of case study: Fossils with "Outstanding Universal Value", and public engagement with the history of life

1. Summary of the impact

Leicester's world-leading research into exceptionally well preserved fossils has crucially underpinned the successful establishment of a new UNESCO World Heritage Site in China. The Chengjiang Fossil Site in Yunnan Province is officially recognised by UNESCO as having "Outstanding Universal Value", containing fossils of soft-bodied sea-life dating from 530 million years ago. The fossils occur in a region where the minerals industry is a key economic driver: granting of World Heritage Site (WHS) status has removed the threat of encroaching commercial mining activities, secured conservation of the site, and paved the way for further sustainable, non-invasive tourism. The same research serves as a vehicle for raising awareness about the evolution of life, the history of biodiversity and the importance of 'blue skies' research in the UK.

2. Underpinning research

'Exceptionally preserved' fossils retain traces of body-parts that under normal circumstances rot-away without trace. These fossils play a disproportionately important role in our understanding of evolution and the history of biodiversity because they provide our only direct evidence of how, when and why the major groups of living organisms, including our deepest vertebrate ancestors, came to have the distinctive body plans that we recognize today. But the processes by which exceptionally preserved fossils came to be fossilized are complex, and disentangling the important biological and evolutionary signals from the noise of post-mortem decay, preservation biases, and geological processes is fraught with difficulties. This is an area in which Leicester's Palaeo3 Group specializes.

The Unit's work in this area has combined three complementary strands of research:

- New anatomical and evolutionary interpretations of exceptionally preserved animals, including work on the earliest known fossil vertebrates, diversity and early evolution of arthropods [**1**-**3**;], primitive deuterostomes, and methods for robust anatomical analysis.
- Detailed analysis of mechanisms of preservation, describing the minerals involved and explaining the process of fossilization of exceptionally preserved fossils, such as those in the Chengjiang biota [**4**].
- Experimental analysis of biases resulting from differential decay of soft-tissues, providing data for the sequence and timing of decay of the characteristics used in identification and interpretation of fossilized soft tissues, allowing analysis of whether fossils look primitive because they rotted to some degree before they were fossilized [**5**].

This third strand - revealing how decay of bodies can distort the fossil record of evolution - has led directly to significant public engagement.

Of particular relevance to this case is a body of research on the anatomy, evolutionary relationships and preservation of Chengjiang fossils. The Chengjiang fossil site was first discovered by Chinese geologist Hou Xianguang. The fossils offer a unique insight into an ecosystem close to the roots of animal biodiversity, illuminating the evolutionary and developmental heritage of many present-day species. Since the 1990s David Siveter, and Richard Aldridge with Derek Siveter (University of Oxford), and other Leicester colleagues, have worked with Prof Hou on the extraordinary finds. This work developed into a long-standing joint research partnership between University of Leicester academics and Prof Hou (now director of Yunnan Key Laboratory for Palaeobiology at Yunnan University, Kunming, China). Leicester's particular contribution to this partnership, which is ongoing, has been the scientific interpretation and analysis of the Chengjiang fossils. This expertise has consistently been at the cutting edge of palaeobiology. It is this interpretation and analysis which have revealed unique insights into the roots of animal biodiversity, leading UNESCO to recognize their Outstanding Universal Value.

In 2005, Professors David Siveter and Richard Aldridge were awarded Guest Professorships at Yunnan University. This collaboration led to an overview of the diversity of the Chengjiang biota [**6**], which provided source material for the UNESCO World heritage bid.

We have applied our approach to a range of world-class deposits of exceptionally preserved fossils (Lagerstätten), including the Burgess Shale (Canada), the Ordovician Soom Shale biota (South Africa), the Silurian age biotas of Herefordshire (UK), the Eramosa (Canada) and, in particular, the Cambrian age biotas of Chengjiang (China), around which this case study centres.

The research team consists of :
Professor Richard Aldridge (Professor 1993-2011)
Professor David Siveter (Reader 1993-2000; Professor 2000-)
Dr Sarah Gabbott (Lecturer 1999-2008; Senior Lecturer 2008-)
Professor Mark Purnell (Research Fellow, 1992-2008; Reader 2008-2011; Professor 2011-)
Professor Mark Williams (Lecturer 2006-2009; Reader 2009-2013; Professor 2013-)
Dr Rob Sansom (Research Associate 2008-2011)

3. References to the research

1. Hou XG, Aldridge RJ, Siveter DJ, & Feng XH (2002) New evidence on the anatomy and phylogeny of the earliest vertebrates. *Proc. R. Soc. Lond. Ser. B-Biol. Sci.* 269:1865-1869.
2. Hou XG, Williams M, Siveter DJ, Siveter DJ, Aldridge RJ, & Sansom RS (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 B-Biological Sciences* 277:1835-1841.
3. Siveter DJ, Williams M, & Waloszek D (2001) A phosphatocopid crustacean with appendages from the Lower Cambrian. *Science* 293:479-481.
4. Gabbott SE, Hou XG, Norry MJ, & Siveter DJ (2004) Preservation of Early Cambrian animals of the Chengjiang biota. *Geology* 32:901-904.
5. Sansom RS, Gabbott SE, & Purnell MA (2010) Non-random decay of chordate characters causes bias in fossil interpretation. *Nature* 463:797-800.
6. Hou XG, Aldridge RJ, Bergstrom J, Siveter DJ, Siveter DJ, & Feng XH (2004) *The Cambrian fossils of Chengjiang, China: the flowering of early life* (Blackwell Science, Oxford).

Grants

- A series of Royal Society International Joint Project Grants with China, on the Chengjiang biota, between 2002 and 2012 (Siveter PI, and others)
- NERC Grant - The problem of vertebrate origins – comparative taphonomy and gaps in the fossil record (Gabbott and Purnell, 2008-2011, £414,541 FEC)
- NERC Grant - Experimental decay of onychophorans – lobopodian anatomy and arthropod origins (Purnell and Gabbott, 20011-12, £52,767)
- SYNTAX Grant - Taphonomic bias in taxonomic and systematic analysis of fossils (Purnell, 2011-14, £18,307)
- Royal Society International Joint Project Grant: Lower Cambrian Chengjiang biota in China. (Siveter and others, 2002-05; with China, £17,446)

Research on experimental decay selected as research highlight by NERC (2010), selected by The Royal Society for the Summer Science Exhibition (2011), awarded bronze medal at SET for Britain 2011 (Houses of Parliament), shortlisted for the Times Higher Education Research Project of the Year Award 2011

4. Details of the impact

A. Conservation of unique fossil site

In 2005, in collaboration with Prof Hou, Siveter and Aldridge (and Derek Siveter from Oxford) were the only academics from outside China asked to help the Yuri Municipal Government – the administrative region within which Chengjiang is located - to prepare an application for World

Heritage Status. From 2008, they worked first on a report from Yuxi to Beijing to secure the site as one of China's official nominations and then on the report to UNESCO which outlined the case for the Chengjiang site [**A**]. World Heritage Site (WHS) status was granted in July 2012 [**B**], following three years of nomination development in which the Unit's research played a key role.

The academics' contribution to this three-year process was extensive; they wrote all the scientific parts of the bid, including details of the global scientific significance of the Chengjiang site, and how it differs from other palaeontological WHS - both of crucial importance in establishing why Chengjiang is deserving of WHS status. Their contribution drew on more than 20 years of research conducted at Leicester which revealed the significance of the fossils (see **A** sections 2 and 3). The first overview of the full diversity of the fossil biota was central to demonstrating that the fossils present are equal if not greater in diversity and quality of preservation than other sites of exceptional preservation already recognized as WHS.

Any country is eligible to send to UNESCO a list of nominees for World Heritage Status. The UNESCO World Heritage Committee, elected by nation states, meets every year to choose the successful nominations – those natural or man-made wonders, which are judged to be in the greatest need of protection. This decision is informed by a report from the International Union for Conservation of Nature, which assesses the respective strengths of each nomination in accordance with the set criteria.

In addition to underpinning the Chinese Government's WHS nomination, the IUCN report itself is also informed directly by Leicester research - the seminal book *The Cambrian fossils of Chengjiang, China: the flowering of early animal life* (of which Siveter and Aldridge were leading authors) is cited as "additional literature consulted''[**C**]. The bid also cites numerous papers by Leicester authors in the bibliography [**A**].

There are significant benefits that come with World Heritage Site status, not least its established influence in world tourism markets, and China itself is benefitting both financially and socially following the success of the application. Economic impacts include increased access to preservation funds and world heritage tourism; societal impacts include significantly increased public interest and awareness [**D**]. On a wider scale, the status impacts on all of mankind's cultural heritage through preservation of a unique physical environment which has revealed – and continues to reveal – important new information about the roots of our collective natural history.

As part of the application, Chengjiang county and Yuxi municipality pledged an annual allocation of at least 6.5 million Chinese yuan (approx. £650,000) to the stable management fund for Chengjiang Fossil Site. This funds onsite patrols, monitoring activities, specimen sorting and cataloguing of fossils from the museum, museum maintenance, staff stipends, promotion and publicity, fossil excavation and research, community training and external/International exchange and cooperation.

The site's nomination for WHS Status had led to increased funding support from Yunnan provincial and the Central government for maintenance of the site [**E**, section 3.2]
Data for visitor numbers for 2012 and 2013 are not available, but Official projections are for visitor numbers rising to 30-40,000 as a direct result of WHS Status.

Much remedial work to redress the effects of mining activity had already been undertaken in the area, and additional work on ecological restoration and forest/grass reclamation of the site is ongoing and will continue as a result of the successful application for WHS status. Importantly, as a result of the WHS nomination, additional protocols [**E**, section 5.3.2], were added to the Chinese legislative system surrounding infrastructure development at the Chengjiang site. The report states: "Compared to the past practices, the infrastructure development projects must go through dual review and approval, implying more strict review and approval protocols.'' This, in effect, will prevent any infrastructure development at the site in future as the management institutions of Chengjiang Fossil Site and the local government now have a veto.[**E**, section 5.32]

B. Fostering interest in science
The Unit's research on exceptionally preserved fossils, combining big questions about evolutionary origins with an experimental approach, serves as a highly effective vehicle for raising awareness

about the evolution of life, the history of biodiversity, and the importance of 'blue skies' research. As well as widespread international, national and local media coverage, this has been achieved through direct contact with school-children, the public and policy makers at a range of events. With funding from the University, The Palaeontological Association, and The Natural Environment Research Council we designed activities and successfully bid for selection at the following events.

- SET for Britain 2011 (Houses of Parliament): direct interaction between policy makers and Britain's early-career research scientists who are driving progress in and development of UK research and R&D. An email received after the event from Richard Fuller (MP for Bedford and Kempston), says "I do take on board your comments re: funding of science – particularly fundamental research'' [**G**].
- The Royal Society Summer Science Exhibition 2011: 13,800 visitors, 32% of whom were school students; visitor questionnaires conducted over several years indicate that 60-70% of students are more interested in a career in science after visiting the exhibition [**F**]**.** The Royal Society event also includes invitation only evening soirees, allowing researchers to interact and engage directly with MPs and policy makers', we took this opportunity to emphasize the excitement and value of 'blue skies' research (we spent 15 minutes with the Minister for Science David Willetts, for example).
- Big Bang 2012 and Big Bang 2013 (UK Young Scientists and Engineers Fair): designed to raise awareness and dispel myths about STEM and careers within STEM. More than 115,000 young people, their teachers and parents attended [**H**] and questionnaires reveal similar levels of increase in the numbers of students interested in careers in science as with the Royal Society, and an increase in the likelihood of parents and teachers recommending scientific careers to children of around 60%. Around 80% of teachers indicate that they will incorporate learnings from the event into their teaching.

5. Sources to corroborate the impact

A. Ministry of Housing and Urban-Rural Development of the People's Republic of China, World Heritage Nomination, Natural Heritage, China, January, 2011 (Nomination file). Documentary evidence for the involvement of DJS and RJA in the preparation of the nomination can be provided on request (Meeting agenda and official certificates from Yuxi Municipal People's Government presented to Siveter and Aldridge recognizing their "outstanding contribution" and providing "proof and encouragement", dated May 2013).

B. United Nations Educational, Scientific and Cultural Organization, Convention Concerning the Protection of the World Cultural and Natural Heritage. Decisions adopted by The World Heritage Committee at its 36th Session (Saint-Petersburg, 2012; WHC-12/36.COM/19)

C. World Heritage Nomination – IUCN Technical Evaluation: Chengjiang Fossil Site (People's Republic of China) – ID No. 1388 in IUCN Evaluations of Nominations of Natural and Mixed Properties to the World Heritage List 2012 (WHC-12/36.COM/INF.8B2)

D. Report from IUCN on sustainable tourism and natural world heritage (http://cmsdata.iucn.org/downloads/sustainable_tourism_and_natural_world_heritage_report.pdf); UNESCO benefits of ratification (http://whc.unesco.org/en/convention/#Benefits-of-Ratification); Social, economic and environmental benefits of World Heritage Sites, Biosphere Reserves, and Geoparks (http://www.snh.org.uk/pdfs/publications/commissioned_reports/Report%20No248.pdf)

E. Ministry of Housing and Urban-Rural Development of the People's Republic of China report to UNESCO, January, 2012, section 3.2

F. Royal Society Summer Science Exhibition evaluation 2011

G. Email from MP for Bedford and Kempston

H. Big Bang Evaluation report