

# New terrestrial limbed vertebrate fossils from Scotland populate Romer's Gap

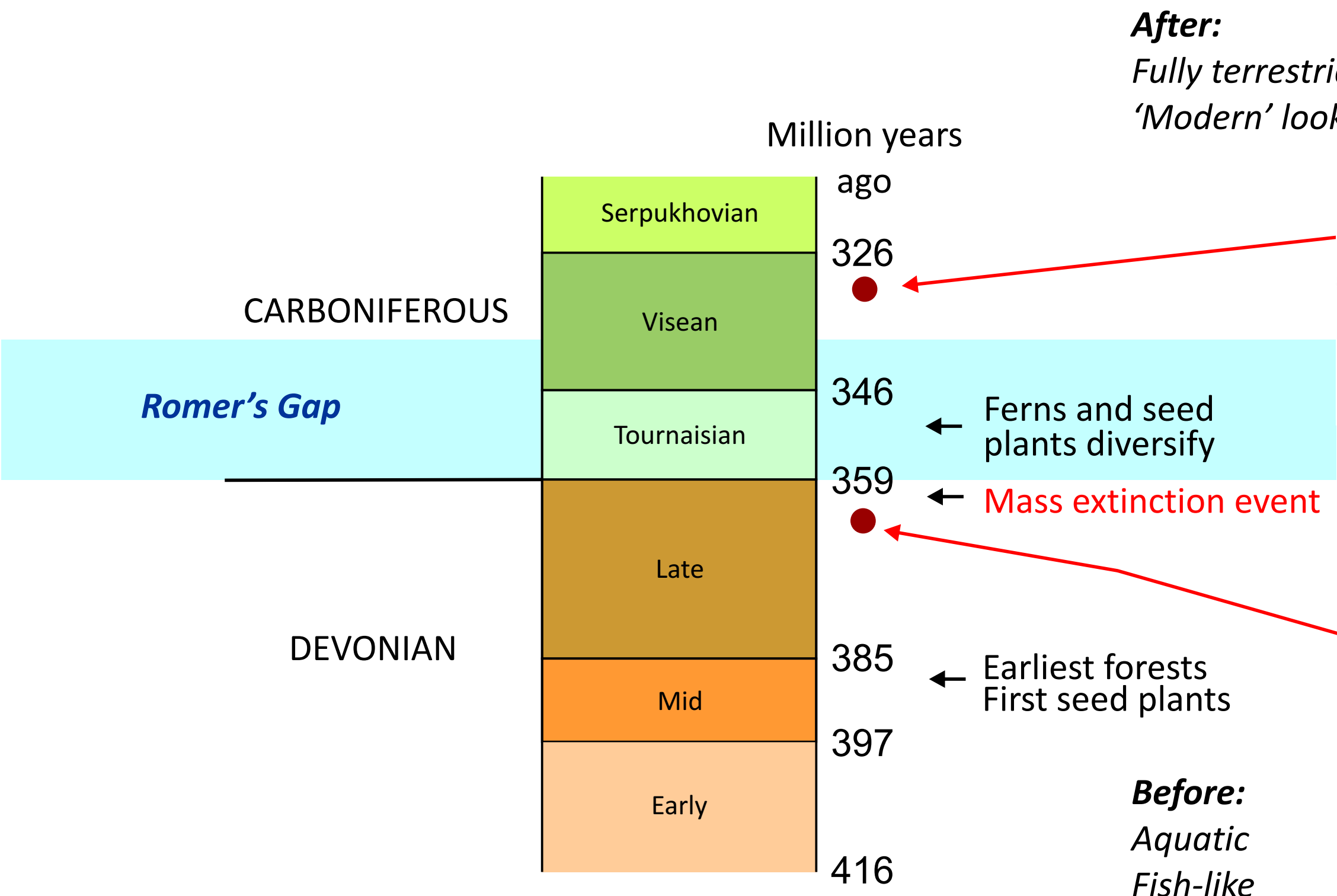
## The TWeed Project - Tetrapod World: Early Evolution and Diversification

### 1 What is Romer's Gap?

When did limbed vertebrates - or tetrapods - adapt to walk on land? How long and under what circumstances did it take to achieve this? And what was the Earth like at this time? These are key questions that shaped the future evolution of life on Earth, including the eventual appearance of humans.

The process began about 360 million years ago at the end of Devonian times when a mass extinction event changed the world for ever. Many fish groups became extinct and their place was taken by modern forms. Modern plant groups, including true ferns and seed plants, diversified. Before the mass extinction tetrapods were essentially aquatic and fish-like, but afterwards they emerged on to land for the first time. The animals seen later in the Carboniferous around 340 million years ago very strongly resemble modern forms.

Until now, the intervening 20 million years has remained almost unrepresented for fossil tetrapods. Thus, we know little about how they evolved adaptations for life on land, the environments in which they did so, and the timing or sequence of these events. The evolutionary relationships among these early tetrapods and how they relate to modern forms are also unclear and controversial as a result of this lack of fossil information. The entire fossil hiatus has been called '*Romer's Gap*' after the American palaeontologist who first recognized it.



After:  
Fully terrestrial  
'Modern' looking

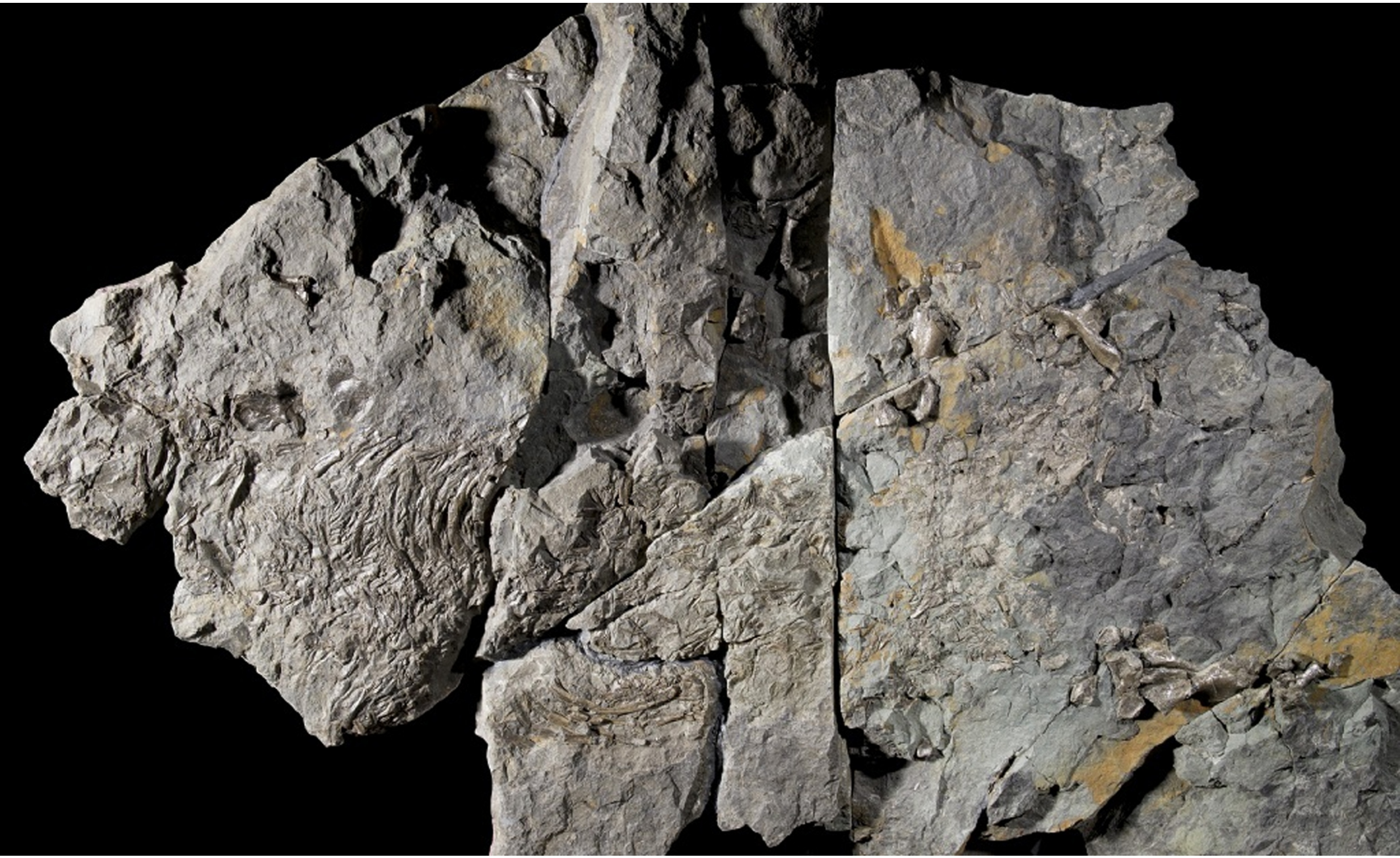


### 2 New tetrapod fossils found in Scotland

Now, for the first time anywhere in the world, new fossil localities that lie within Romer's Gap have been found in south-eastern Scotland. These have already provided a wealth of new fossils of tetrapods, fish, invertebrates and plants.

During the next 4 years the TWeed project team will be the first to have the opportunity to study these specimens and to search for others. Team members will also investigate the environmental, depositional, and climatic context in which this momentous episode took place.

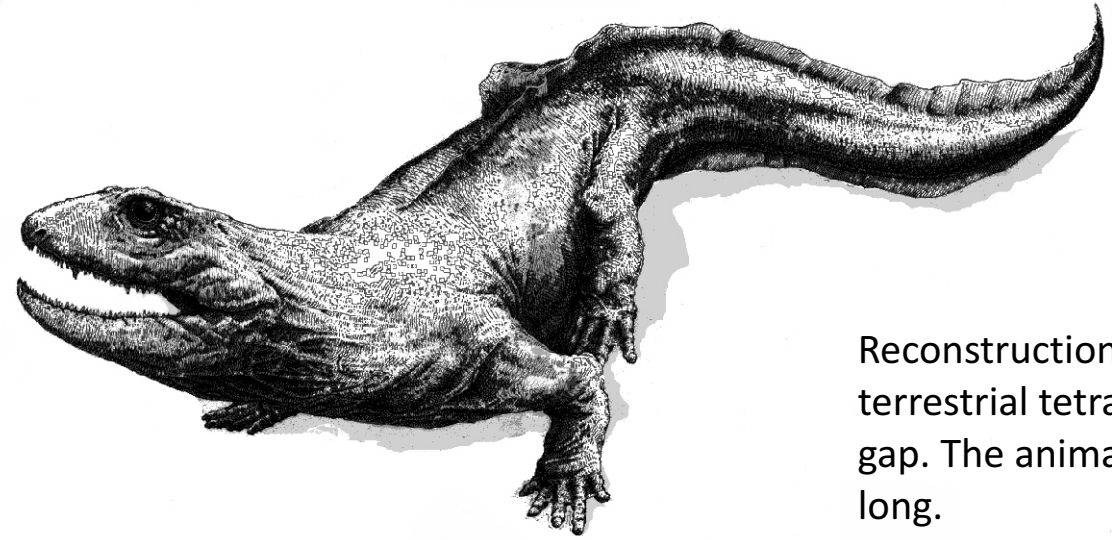
The project team is led by the University of Cambridge, with members from the universities of Southampton and Leicester, the National Museum of Scotland and the British Geological Survey. The project is funded by the Natural Environment Research Council.



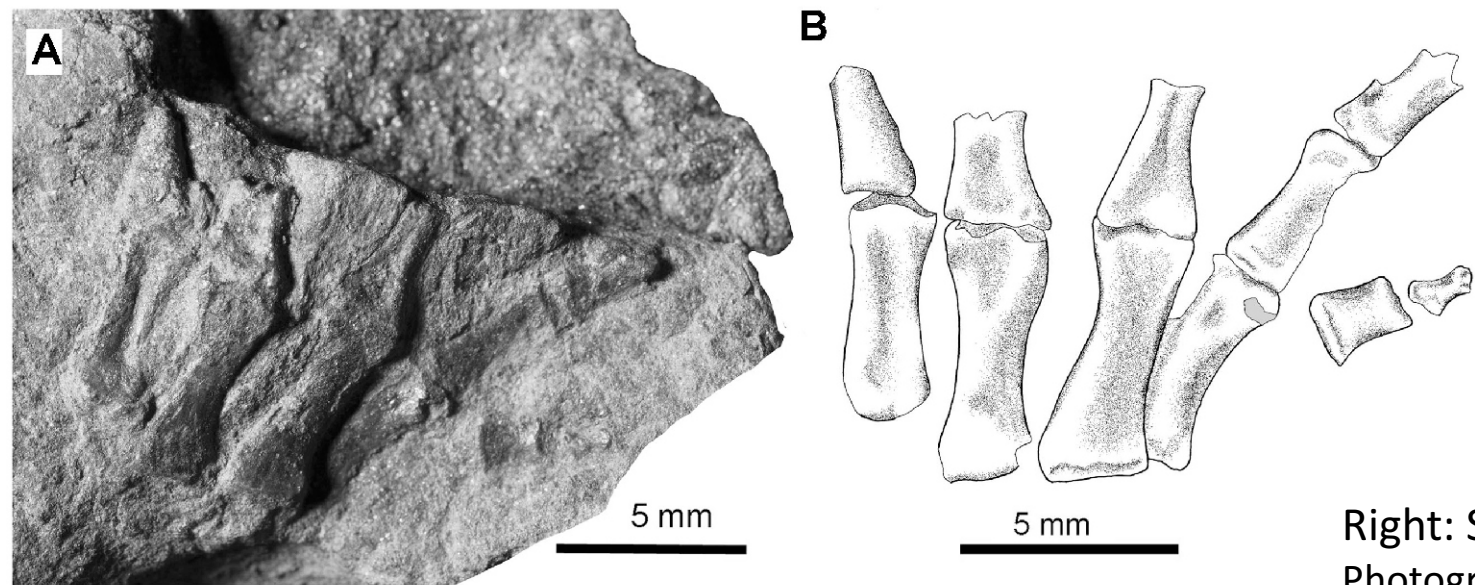
Right: semi-articulated skeletal remains of a small tetrapod from the Borders, named as 'Ribbo', skull bones to the left, hind legs to the right. Specimen is about 60 cm across.



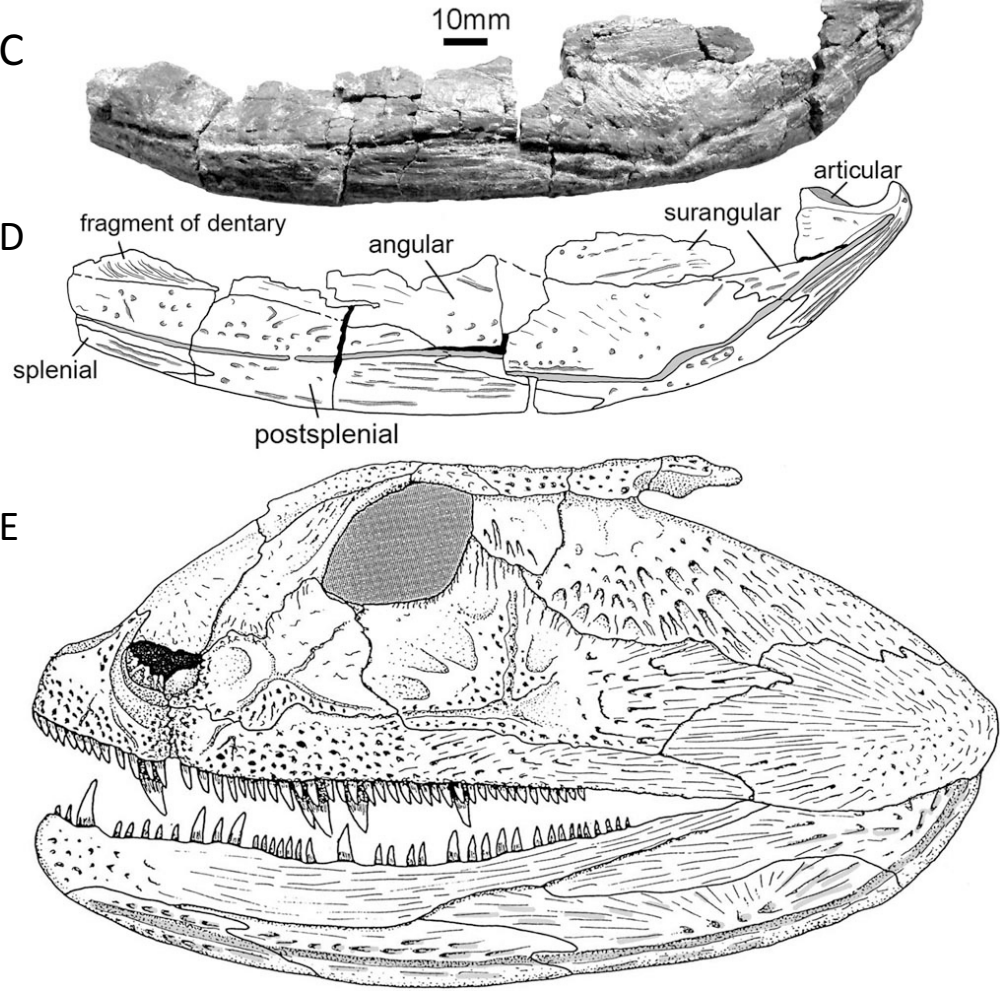
Above: Tim Smithson, Stan Wood and Jenny Clack  
Left: Stan Wood, collecting 'Ribbo'.



Reconstruction of 'Ribbo', a terrestrial tetrapod from Romer's gap. The animal is about 80 cm long.



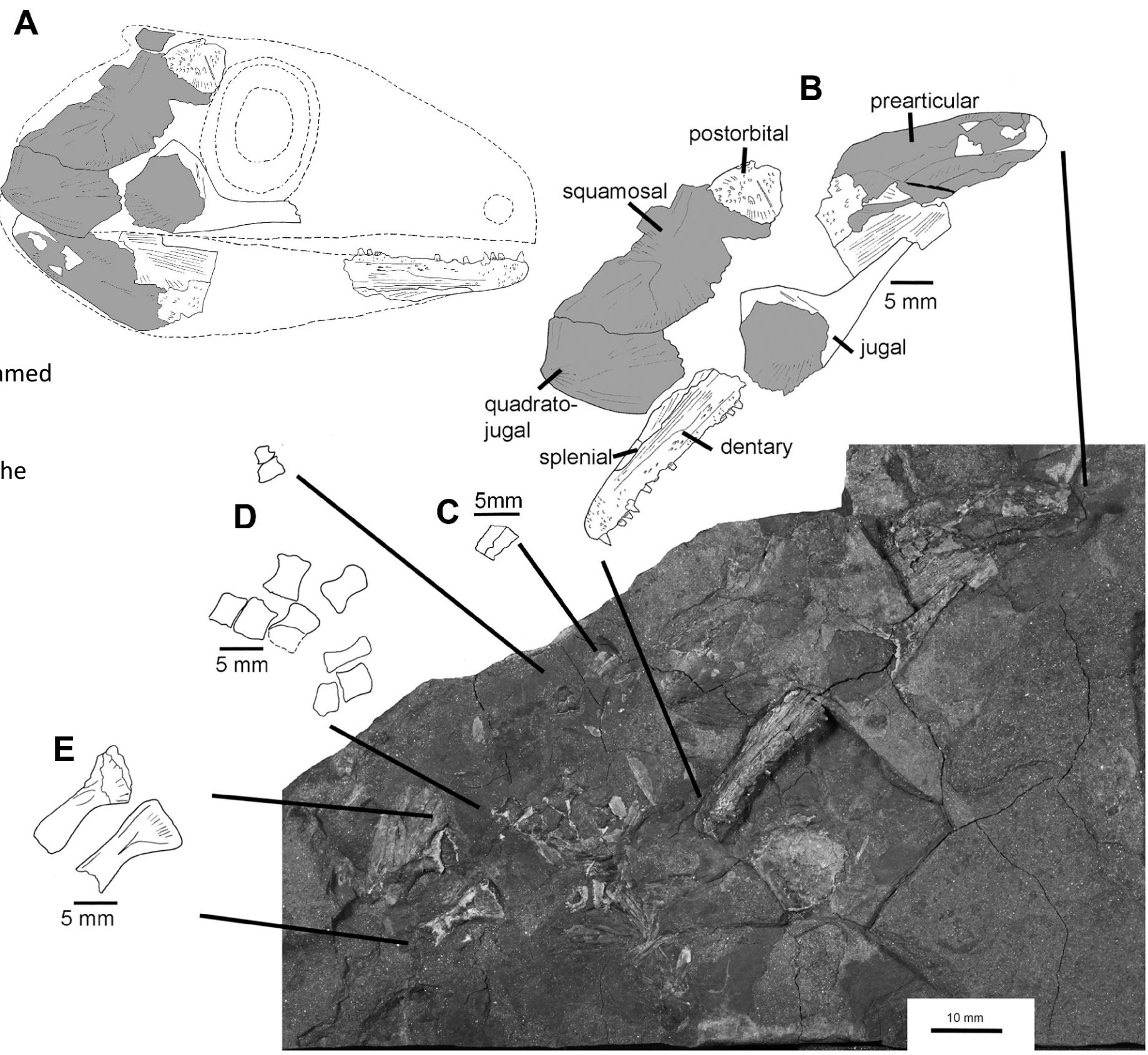
Right: Specimen from the Whiteadder River  
Photograph and interpretative drawings of a new, unnamed tetrapod (Specimen UMZC2011.7.2)  
A Reconstruction of skull  
B Diagram of the cheek and lower jaw used to create the reconstruction, in position on the specimen.  
C Two sclerotic plates  
D Digit elements  
E Radius and ulna  
In A and B the grey shading indicates the natural mold.



Left: Burnmouth specimens  
A, B Five-toed hand or foot (Specimen UMZC2011.8), photograph and interpretative drawing.

C, D *Crassigyrinus*-like partial lower jaw (Specimen UMZC2011.9.1), photograph and interpretative drawing.

E reconstruction of the skull of *Crassigyrinus scoticus* from the Early Carboniferous of Scotland.



Map with the locations where tetrapod fossils have been found recently. The blue areas are the outcrops in the Midland Valley of Scotland and the Borders of the strata that host the fossils (Ballagan Formation - see below).



The new finds have reported in the scientific press recently:

T R Smithson, S P Wood, J E A Marshall & J A Clack 2012. Earliest Carboniferous tetrapod and arthropod faunas from Scotland populate Romer's Gap. *Proceedings of the National Academy of Sciences USA* Vol 109 (12), 4532-4537.

### 3 The early tetrapod world

The fossils are all from the Ballagan Formation, a distinctive rock unit that crops out widely across the Midland Valley of Scotland, East Lothian and the Borders through into Northumberland. The strata are Tournaisian - earliest Carboniferous - in age.

The Ballagan Formation is a cyclic succession of mudstone, with interbedded sandstone and thin beds and nodules of 'cementstone'. These strata were formerly included within the 'Cementstone Group' of northern England and the 'Calcareous Sandstone Measures' of central Scotland.

These rocks were deposited on an extensive, low relief, muddy floodplain that was traversed by meandering streams flowing from the north and north-east. Periodically, the river-derived floods submerged the floodplains generating extensive shallow freshwater floodplain lakes including some that were more permanent. The widespread presence of gypsum and pseudomorphs after halite, particularly in the Midland Valley of Scotland, suggests that these were marginal marine coastal floodplains that were subject to occasional marine transgressions and fluctuating salinity.



Exposure adjacent to the Whiteadder River illustrating many of the characteristics of the Ballagan Formation. The lower part shows repeated thin cycles of mudstone, siltstone, fine-grained sandstone and thin hard beds of 'cementstone'. The thicker bedded unit of sandstone in the upper part of the section fills a shallow channel carved into the underlying strata.

#### Project aspirations

The collaborative nature and efforts of our team, with its wide range of experience and expertise can, for the first time anywhere in the world:

- Provide a coherent picture of the biological, environmental and geological conditions during the 15-20 million years recovery period following the mass extinction event at the end of Devonian times.
- Explore and explain the changes during this period that laid the foundations for the emergence of modern fauna and flora, and when tetrapods underwent a major radiation into diverse groups including predominantly terrestrial forms for the first time.
- South-east Scotland is the only place so far known in the world where we can obtain this quality and depth of data to understand a crucial period of Earth history: it is of international significance.



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