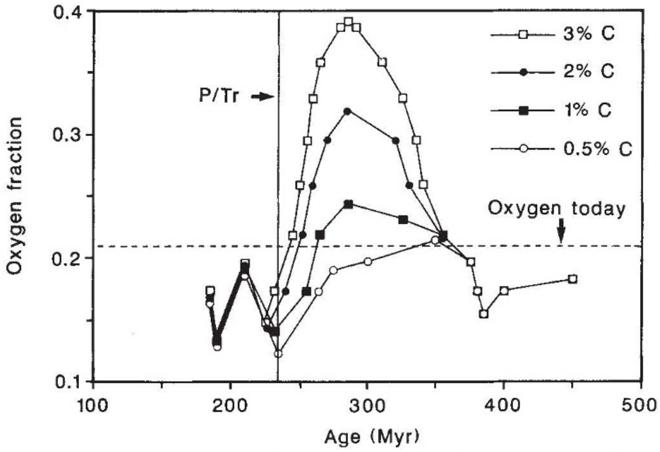


Concentration of atmospheric oxygen as a function of geological age calculated via a sedimentary rock abundance model (adapted from ref. 7). Different curves are for the indicated average percentage of organic carbon in coal basin sediments, and the Permian/Triassic boundary is indicated by the vertical line marked P/Tr. The model is based on the relative proportions of sedimentary clastic rocks of this age that are present as coal basin sediments[8], reasonable assumptions regarding original worldwide sedimentation rates[7], the estimated range in the content of coal plus non-economic disseminated organic matter in coal-bearing sands and shales[5,9], and the average organic carbon content of marine sediments[8]. Organic burial rates, on which much of the oxygen results depend, agree with those calculated from independent models based on the use of carbon isotopes.

disseminated non-economic organic matter, in coal-basin sediments is about 2.5 per cent C. Thus, excessive burial of organic matter during the Carboniferous and early Permian may have resulted in elevated levels of atmospheric oxygen.

Later in the Permian, burial of organic matter on land declined, probably because of increasing aridity accompanied by less extensive swamp formation. (The preservation of organic matter on the continents is dependent on its deposition in standing water, such as in lakes and swamps, where the material is protected against oxidative destruction.) Organic-rich swamp and lake sediments were replaced by organic-poor continental red beds[8]. Red beds contain very little organic matter because they are formed in well-drained, fully aerated environments. Greater aridity should also have resulted in decreased transport of organic matter by rivers to the oceans because of both lower biological production on land and decreased river flow. Because of lower sea level at that time, increased sedimentation occurred on the continents at the expense of marine sedimentation, which also resulted in decreased organic burial because marine sediments are considerably higher in organic matter than red beds. The emerging continents plus increasing aridity must have involved a drop in worldwide sedimentary organic matter burial and worldwide oxygen production. Because of continued uptake of $O_2$ by the weathering of pre-existing organic-rich rocks, this drop probably also resulted in a drop in the level of atmospheric oxygen as shown in the figure.

I therefore conclude that a primary factor in causing a drop in both the $^{13}C/^{12}C$ ratio of sea water and the concentration of atmospheric oxygen during the Permian was the drying up of the continents. It is not clear what brought about this climate change.

Robert A. Berner
*Department of Geology and Geophysics, Yale University, New Haven, Connecticut 06511, USA*

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# Malarial proteinase?

SIR—The DNA sequence encoding a major blood stage antigen of *Plasmodium falciparum* has recently been determined[1,2]. This sequence codes for a protein (relative molecular mass 111,000) of over 980 amino acids which is found abundantly in the parasitophorous vacuole of the erythrocyte stage and is processed to yield peptides at the merozoite release and reinvasion stage. Much interest has been focused on this antigen as a possible source of a vaccine against malaria as it is found to induce limited immunity in monkeys[3]. The function of the protein is unknown but using homology search[4] and multiple alignment software[5] we have now found that it shows weak but significant similarity to the cathepsin L, B and H group of cysteine proteinases.

Similarity among the cysteine proteinases is concentrated in two regions around the active site of the proteins; it is in these regions that the *Plasmodium* sequence shows greatest similarity. The figure shows an alignment of a diverse group of cysteine proteinases with the *Plasmodium* sequence around these two active-site regions. The putative active-site cysteine and histidine residues are highlighted. Outside these two active-site regions, the similarity between the different proteins is weak overall.

Dr Yongyuth Yuthavong (Mahidol University, Bangkok) has pointed out to us that proteases are known to be of major importance in the life cycle of *Plasmodium*, either for the degradation of haemoglobin during the erythrocyte stage, or for the cleavage of cell-surface proteins during the merozoite stage. Furthermore, a variety of protease inhibitors, including ones specific for cathepsin L, interrupt the normal life cycle of the parasite[6]. The sequence similarity reported here strongly suggests that the 111-K antigen, or a cleavage fragment of it, is a cysteine proteinase, making an already important protein even more interesting.

DESMOND G. HIGGINS
DAVID J. McCONNELL
PAUL M. SHARP
*Department of Genetics, Trinity College, Dublin 2, Ireland*

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Barley aleurain              ..157aa PVKNQAHCGSCWTFSTTGALEAA ..123aa.. DDVNHAVLAVGYG----V-ENGVPYWLIKNSWGADWGDNGYFK
Papain (Carica papaya)       ..137aa PVKNQGSCGSCWAFSAVVTIEGI ..118aa.. NKVDHAVAAVGYG---------PNYILIKNSWGTGWGENGYIR
Rat cathepsin H              ..128aa PVKNQGACGSCWTFSTTGALESA ..125aa.. DKVNHAVLAVGYG----E-QNGLLYWIVKNSWGSNWGNNGYFL
Rat cathepsin L              ..127aa PVKNQGQCGSCWAFSASGCLEGQ ..122aa.. KDLDHGVLVVGYGYEGTD-SNKDKYWLVKNSWGKEWGMDGYIK
Slime mould cathepsin        ..131aa PVKNQGQCGSCWSFSTTGNVEGQ ..128aa.. NSLDHGILIVGYSAKNTIFRKNMPYWIVKNSWGADWGEQGYIY
Plasmodium 111K antigen      ..577aa QVEDQGNCDTSWIFASKYHLETI ..150aa.. DTADHAVNIVGYGNYVNSEGEKKSYWIVRNSWGPYWGDEGYFK
                                     ·●··●– ●···● ●··    ·●·            ·· ·●·–  ●●●–           ●–···●●●●  ●● ·●●·
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Residues identical across all six sequences are indicated by (●); positions where four sequences exactly match the *Plasmodium* sequence are indicated by (–); positions showing only conservative[5] amino-acid replacements are indicated by (·), and the two putative active-site residues are indicated by (!).