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Fold belts and mountains: collision of plates or collision of ideas?

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Most research into the geomorphology of mountains since the 1970s accepts the plate tectonic explanation of mountains, that mountains are a result of collision along converging plate boundaries. For example, the first paragraph of Chapter 2 in Owens and Slaymaker (2004) states that mountain systems "are major belts of pervasive deformation". But this is true only of some mountains – others such as the Drakensberg, are formed on horizontal strata. Equally, many of the Earth's plains are formed in areas of pervasive deformation – those of the Amazon Basin, Western Australia and Uganda are good examples. There is no simple relationship between mountains and folding, or any other structure. Standard plate tectonics does little to explain most mountains (see Ollier and Pain, 2000, for a much more detailed treatment).

Since many mountains are not on folded rocks and for those that are there is no relationship between the timing of folding and the timing of uplift, it seems clear that the folding did not make the mountains. We suggest mountains are formed by vertical uplift of originally flat areas with or without pre-existing folding to form plateaus, which may then be eroded to form mountains. Indeed there is one class of mountains, the Great Escarpments, such as the Drakensberg (South Africa) and the Western Ghats (India) that are escarpments at the eroded edge of plateaus (Ollier, 2004).

A lot of folding is caused by gravity sliding, well-known and documented since the days of van Bemmelen (1954). The Niger Delta has most of the fold and fault features of a classical mountain range such as the Apennines or European Alps, but has never been above sea level or 'compressed' between plates as in the standard model: the structures can only be created by gravity sliding. Gravity spreading can also affect any fault blocks raised by more than about a kilometre, as shown long ago by Jeffreys (1931). The Andes are not made by subduction of the Pacific under the South American Plate, as there are thrusts in the opposite sense on the eastern margin. A few have invoked subduction of Brazil in addition (by no means part of the regular plate tectonic paradigm) but perhaps it is more probable that the uplifted Andes block is spreading. Similarly the Tibet Plateau is bounded by the Himalayas in the south and the Kunlun in the north, with allegedly convergent subduction. The north-south trending Rocky Mountain Plateau is bounded by the Park Range on the east and the Front Range to the west, suggesting divergence. Other blocks in the region are similar, with a Precambrian core to an anticline, and divergent spreading, but some trend east-west (e.g. Uinta), others north-west-southeast (e.g. Wind River Mountains). It is geometrically impossible for bounding blocks to be moving in several directions simultaneously.

Most mountain ranges of Europe are currently explained in terms of plate tectonic collision, but this too has many problems. To illustrate just one, the North Apennines are thought to be thrust north, and the Southern Alps to be thrust south. The two opposing nappe fronts are on a collision course, but there is no compression between them and no uplifted fold belt. Instead there is the Po Plain, underlain by essentially conformable and horizontal sediments in an area that has been quietly subsiding for the past 25 million years at least.

Planation surfaces are described on many mountain chains of the world and most geomorphologists agree that they represent erosion surfaces created close to past base level (sea level) and later uplifted. The rocks affected by planation were previously folded, faulted and sometimes overthrust for tens of kilometres. Such is the case in the Andes of Ecuador (Coltorti and Ollier, 2000). The processes that folded and metamorphosed the rocks did not form the mountains, as mountain creation through uplift occurred much later. It cannot be overstressed that although some of the rocks are folded, the Andes are formed basically by vertical uplift after planation. It is also worth stressing that the Andes range includes the largest granite batholith in the world. This is mainly Cretaceous, and older than the Andes and their presumed subduction, and the batholith is also eroded to a plain. Similar planated granites are found in many other ranges, including the Eastern Highlands of Australia.

A planation surface is an important feature in Earth history that marks the end of a tectonic regime. In elementary diagrams compression is shown as causing simultaneous folding and corrugation of the ground surface to make mountains. But in most mountains the ground surface is *not* folded, and commonly plateaus are preserved in almost horizontal position.

Many planation surfaces can be dated, by a whole range of techniques including, for example, K/Ar dating of basalts. If it is accepted that the mountains are formed by vertical uplift of these areas to form plateaus, then we can estimate the age of uplift, and so the age of mountain building. These estimates led to a surprising discovery: most of the world's mountains were uplifted in the last 8 million years and much of the uplift occurred in the last two million years (Ollier and Pain, 2000). The implications of this 'Neotectonic Period" are still being evaluated, but one conclusion is clear: the time scale of mountain building is not that of plate tectonics, which has supposedly been active for at least 200 Million years.

Owen (2004) presented the conventional plate tectonic account of mountain building at plate collisional boundaries, but he notes that some do not fit. He wrote: "These 'ancient' mountain systems generally have little or no relationship to the present lithospheric plate boundaries and may have begun to have formed many hundreds of millions ago." This assumption that mountains that do not fit the plate tectonics pattern are all ancient is false.

The mountains of deep continental interiors, rift valleys or passive continental margins all fit into the Neotectonic Period, and were formed essentially at the same time as mountains on so-called active continental margins.

References

Coltorti, M. and Ollier, C.D. 2000. Geomorphic and tectonic evolution of the Ecuadorian Andes. Geomorphology 32, 1–19.

Jeffreys, H. 1931. On the mechanics of mountains. Geol. Mag., 68, 433-442.

Ollier, C.D. 2004. The evolution of mountains on passive continental margins. Ch.3, 59-88 in Owens, P.N. and Slaymaker, O. (Eds) 2004. Mountain Geomorphology. Edward Arnold, London.

Ollier, C.D. and Pain, C.F. 2000. The Origin of Mountains, Routledge, London, 345pp.

Owen, L.A. 2004. Cenozoic evolution of global mountain systems. Ch. 33-58 in Owens, P.N. and Slaymaker, O. (Eds) 2004. Mountain Geomorphology. Edward Arnold, London.

Owens, P.N. and Slaymaker, O. (Eds) 2004. Mountain Geomorphology. Edward Arnold, London.

van Bemmelen, R.W. 1954. Mountain Building, Martinus Nijhoff, The Hague, 177pp.