

## Tectonics and Magmatism of the Andes

Prof Donny Hutton (University of Birmingham)

Donny explained that his main interests are in the Earth's tectonic plate collision zones where both mountain building (Orogeny) and volcanism occur.

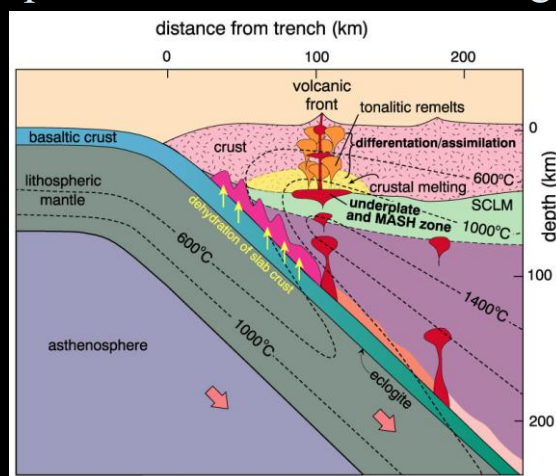
In particular he has been involved in the northern Andes, in collaboration with a team from the University of Bristol, to study the origins of copper mines for mining companies. While undertaking this work he was able to study the structural geology of the Andes and the detailed processes that formed them. This has led to an improved understanding of tectonic plate collisions and in particular the subduction processes involved.



The Andes

The Andes are an 8000km long mountain range and a type example of Ocean/Continent subduction of the Pacific plate under the South American plate.

### Chapter 17: Continental Arc Magmatism



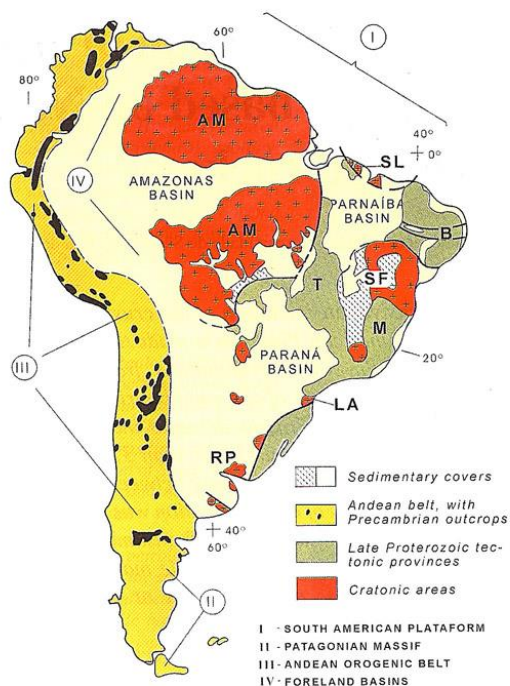
**Figure 17-23.** Schematic cross section of an active continental margin subduction zone, showing the dehydration of the subducting slab, hydration and melting of a heterogeneous mantle wedge (including enriched sub-continental lithospheric mantle), crustal underplating of mantle-derived melts where MASH processes may occur, as well as crystallization of the underplates. Remelting of the underplate to produce tonalitic magmas and a possible zone of crustal anatexis is also shown. As magmas pass through the continental crust they may differentiate further and/or assimilate continental crust. Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall.

Magmatism occurs in the subduction zone as the oceanic crust is subducted underneath the continental crust. Seawater is subducted along with the crust and lowers the melting point of the rocks as well as changing the chemistry. At a particular depth (shown by the yellow dotted line in the figure above) complete melting occurs and the lighter melt rises up into the continental crust. This causes crustal melting incorporating some of the crust minerals in the melt. The final magma collects in 'Magma Chambers' and with increasing pressure eventually erupts as volcanoes. The final erupted material is called 'Andesite' named after the Andes where it was first identified.



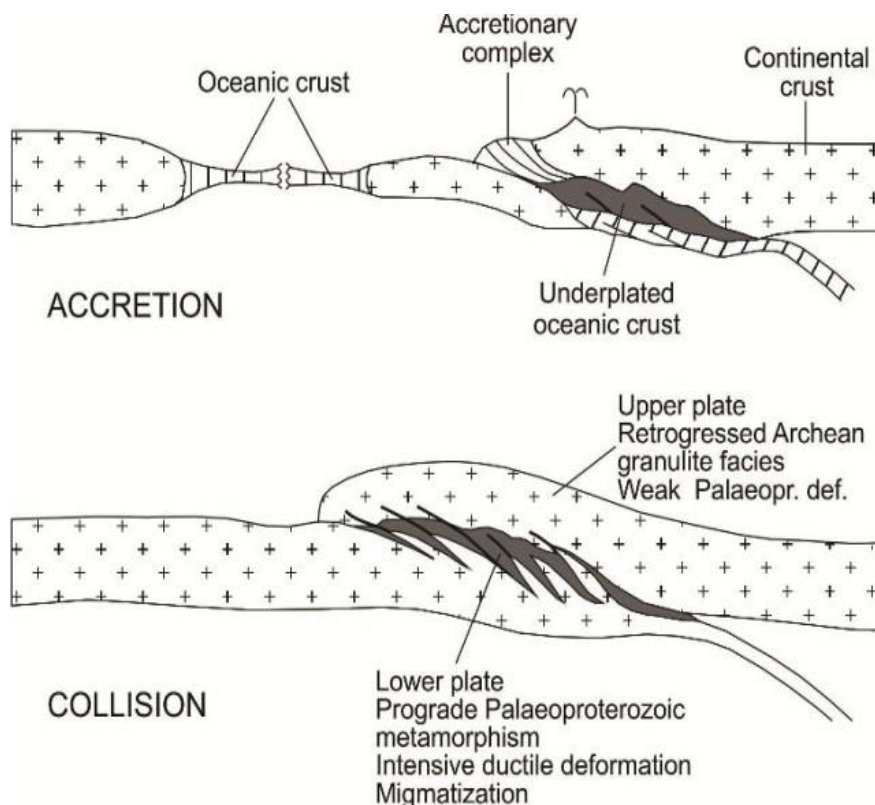
## Andesite

### CRUSTAL PROVINCES OF SOUTH AMERICA



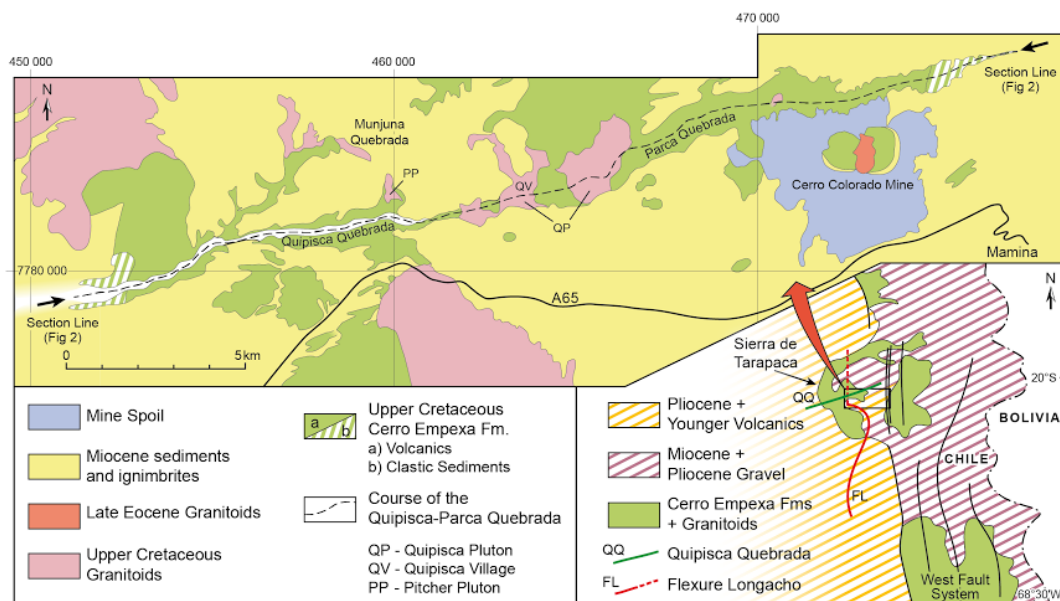
The diagram above shows the main crustal provinces of the South American crustal plate. The central region is dominated by ancient Cratons (red) which were the original parts of the continent. The yellow western side is all formed by much younger plate collision processes although Precambrian fragments (black) have been incorporated.

In addition to volcanism, mountain building also occurs in the yellow region by mechanical accretion, thrusting and uplifting as the plates collide. The following diagram shows how these processes work.



### Colliding Plates

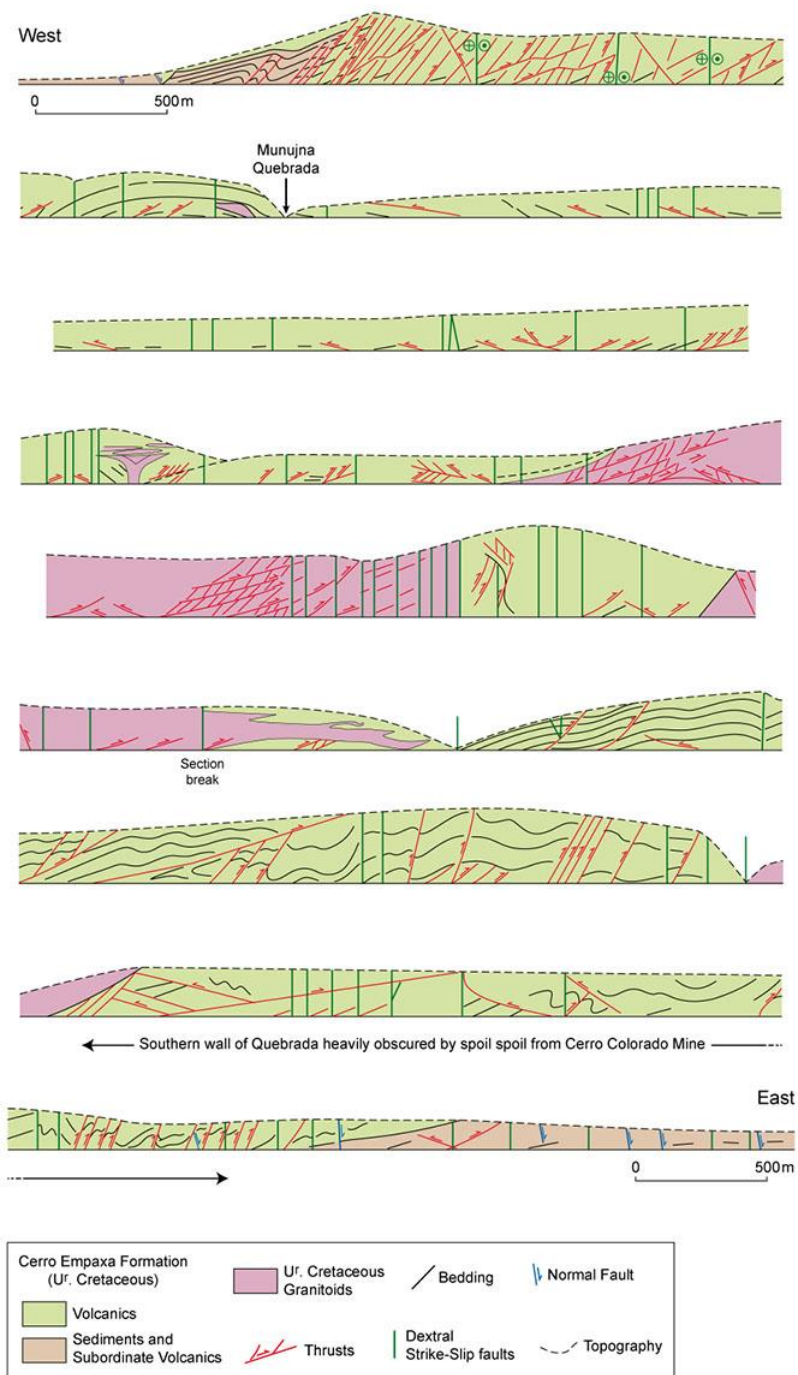
Donny then went to describe his extensive field studies in the Northern Andes in Quipisca-Parca Canyon some 30 km in length.



### Quipisca-Parca Canyon

The canyon has a complex mixture of igneous granites and Andesites together with sedimentary rocks. Donny's field work has resulted in a detailed mapping of the rock types and faulting along the canyon. His work has led to a more detailed and accurate explanation about how the Andes and associated regions were formed by combinations of magmatism, faulting and folding occurring at different times.

The following diagram shows Donny's results for the whole canyon:

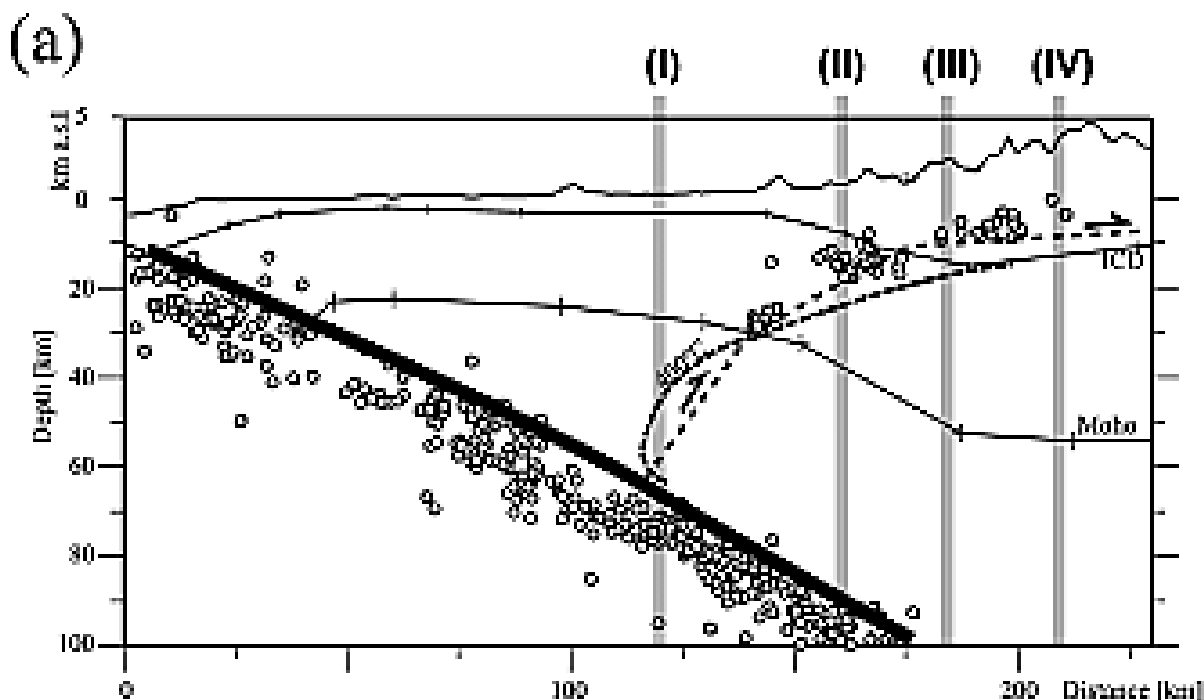


Two overall features and anomalies have become apparent. The first is that most of the many faults in the canyon can be seen to be dipping to the West. However the simple model in the earlier diagram of colliding plates and subduction should result in faults that dip to the East. The second is that the regions of magmatism are distinct and separated indicating that they were episodic with periods of inactivity.

Donny has formulated theories of how these apparent anomalies have occurred.



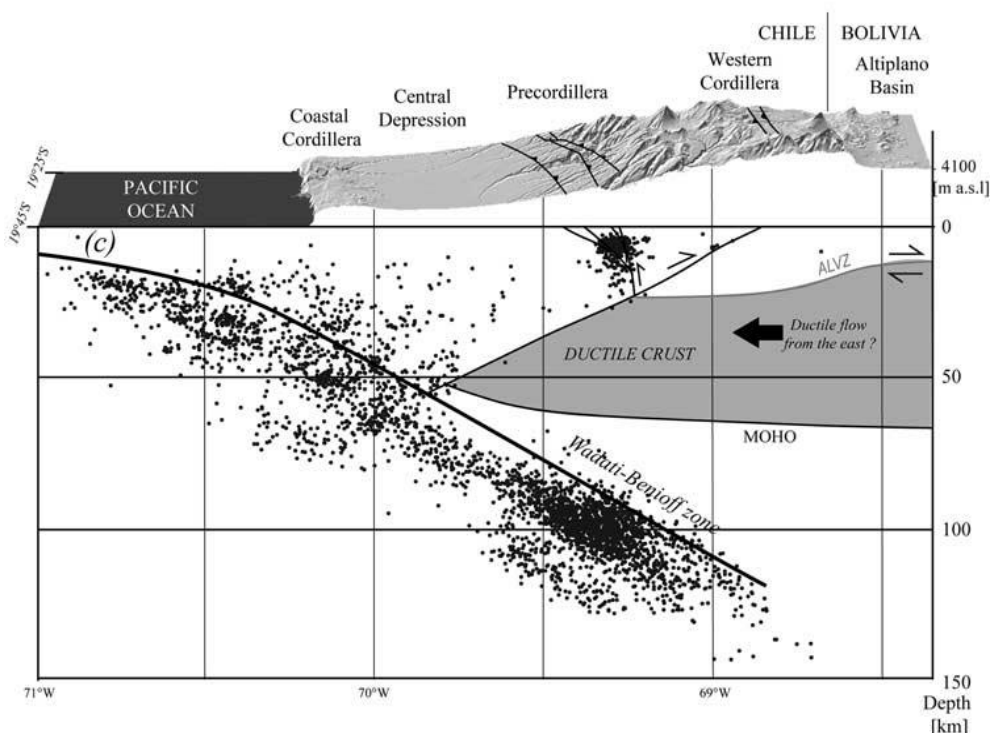
Dealing first with the 'wrong' fault dipping direction detailed earthquake data in the region is summarised the following diagram:



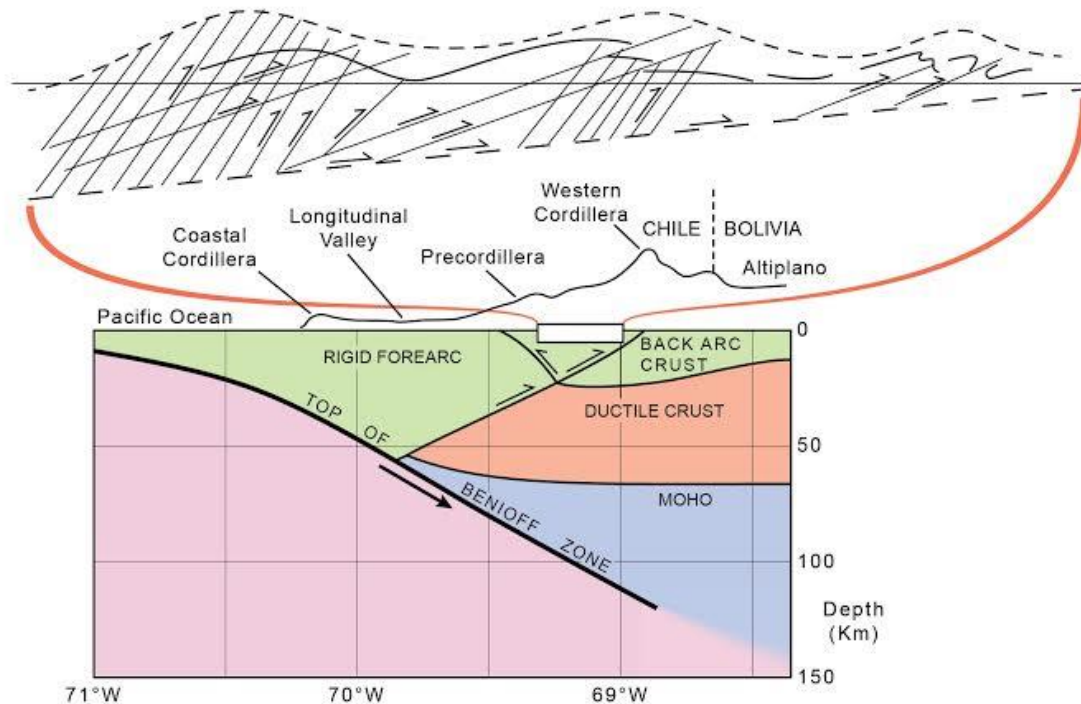
### Earthquake Locations

This clearly shows the principle locations of earthquakes lies, as expected, along the descending line of subduction of the Pacific plate. However a secondary line is apparent running almost at right angles to the line of subduction with decreasing depth from East to West. This suggests that there is an unexpected feature which is causing the faulting as seen on the surface.

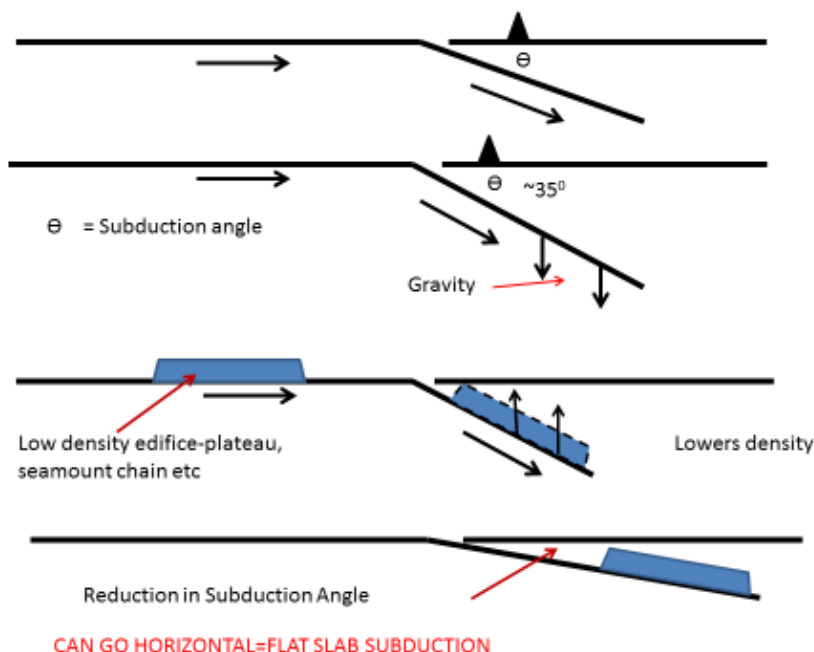
This evidence has been interpreted in the following diagram:



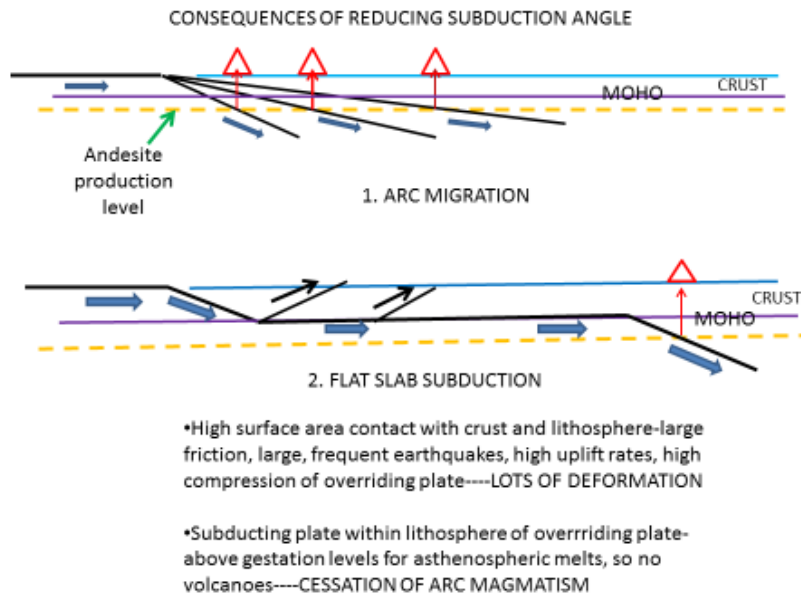
The theory is that there is a region of ductile crust moving from East to West which in interacting with the descending Pacific plate and producing the predominantly West dipping faults at the surface. This is shown in the following diagram:



The second anomaly concerning the episodic nature of the magmatism is speculated to have arisen from major changes in the angle of subduction of the Pacific plate over time. The idea is that at times low density portions (e.g. Seamount Chains) of the Pacific oceanic crust get subducted. For a period of time this lowers the density of the subducting material and causes, due to lower gravitational forces, the subduction angle to reduce even to the point of being near horizontal. After the lower density material moves away the subduction angle returns to normal values. This is illustrated in the following diagram:



The episodic variation in the subduction angle can result in displacement of the region where Andesite magma is produced and even times when no melting occurs because the angle has become nearly horizontal. This is illustrated in the following diagram:



Donny's is in the process of publishing these ideas that may explain what is observed in the Andes. These ideas may also be relevant to other similar plate collision regions in the world.

Dick Harris

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