

# Earthquake-generated ground motion amplification

## Assessing the hazard in urban Costa Rica

by Peter Jackson, David Gunn, Martin Culshaw  
& Alan Forster, *Keyworth*

**G**round motion amplification (GMA) is the increase in amplitude of seismic waves as they pass from harder to softer rocks, plus increases in amplitude due to interactions within 'basin' structures containing soft sediments.

Many of the massive urban developments, or megacities, are founded on flat-lying soils that are relatively easy to engineer. They often coincide with alluvial basins, deltas and lake deposits, where unconsolidated sediments overlie consolidated, crystalline or cemented bedrock. In these circumstances, GMA can pose a serious threat.

A full evaluation of the GMA hazard should be undertaken deterministically.

This requires an understanding of the seismo-tectonics affecting the region, a site-scale layer model of the lithologies from the rock basement to ground surface, data on the geophysical properties of each layer, and digital seismograms of representative earthquakes that would affect the site.

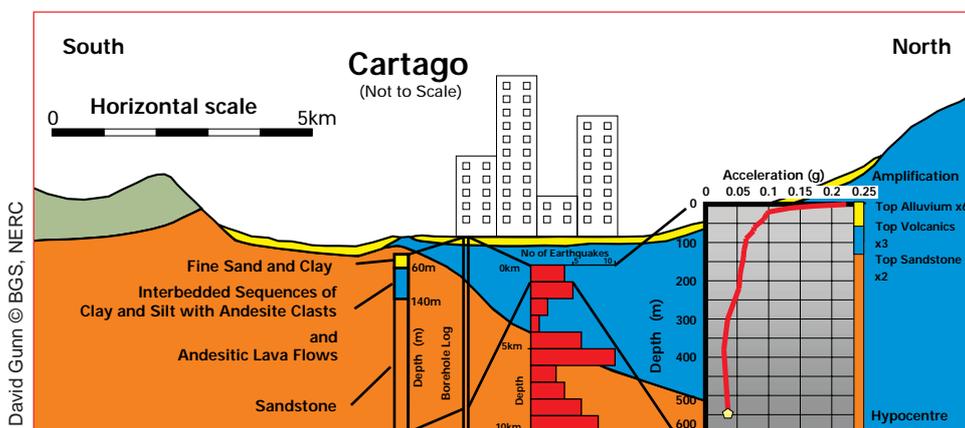
San José, Costa Rica's capital, is situated on the interbedded deposits of lahar of a clay-silt matrix with andesite clasts and andesitic lava flows. Cartago is situated on a sequence of fine sand and clay lake deposits, 60 metres in thickness, in a shallow basin within the lahar and lava flow deposits. All these deposits are underlain by sandstone. The histogram shows that most of the

earthquakes in the locale occur within 10 kilometres of the Earth's surface. Even earthquakes of medium magnitude can cause severe damage because of the combination of proximate shallow earthquakes and the susceptibility of the Cartago basin to GMA. The model results show the amplifying effect of the Cartago basin in comparison to the ground motion suffered in the lava and lahar deposits. Cartago regularly suffers more damage than San José. The peak horizontal acceleration of seismic waves is amplified as they propagate up from the hypocentre because the rocks get weaker towards the surface. The amplification factor is only threefold at the top of the interbedded lavas and lahars where San José is situated but is sixfold at the top of the alluvium where Cartago is situated.

It is apparent that there is a very low level of awareness of the hazards associated with earthquakes. Small-scale surveys alone would improve awareness of the possible hazards in these areas, and this in itself is requested by politicians and national planners. Even in areas like the Central Valley of Costa Rica which are well studied it is apparent that regional and district-scale studies are required to characterise the local impact of hazards. Aspects of future work include further regional studies to map the occurrence of GMA and other earthquake-induced hazards, and greater exchange between geologists and planners such that geological information is input directly into planning decisions.

In conclusion, it is imperative for the geological framework to enter the planning process, as it provides simple guidance to the areas of least and highest susceptibility to GMA.

This information feeds directly into policies for building regulations and design. For example, buildings in Cartago should be designed to withstand greater ground accelerations than buildings in San José. However, often this is not the case due to a lack of awareness amongst planners of the geological controls on hazards. This situation needs to be addressed if the damage associated with earthquakes is to be minimised.



Section showing the cumulative amplification of an earthquake as it passes from hard rocks to soft alluvium beneath Cartago.