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From Kutch to Kashmir: Lessons for use

- Seismic Destruction: Why is Kashmir so Vulnerable?
- Gujarat's Long Earthquake History
- What Controls the Strength of the Ground Shaking During an Earthquake?

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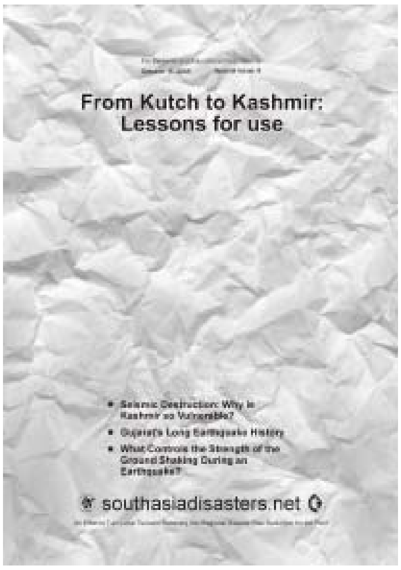
An Effort to Turn Local Tsunami Recovery into Regional Disaster Risk Reduction for the Poor



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In this issue

From Kutch to Kashmir: Lessons for Use

Since, October 11, 2005 early hours AIDMI team is in Kashmir assessing losses and needs. The biggest gap found is of understanding earthquake. Five key gaps are addressed here.

Understanding India's vulnerability: Using earthquake science to enhance disaster preparedness

Every year, thousands flock to Kashmir, in India and Pakistan to marvel at her spectacular scenery and majestic mountain ranges. However, the reality of our location and mountainous surroundings is an inherent threat of devastating earthquakes. In addition to accepting earthquakes as a South Asian reality, we as humanitarian respondents as well as risk reduction specialists must now look to science to enhance disaster risk mitigation and preparedness.The humanitarian communalities know little about what scientific communities have discovered and what could be used to mitigate risk of earthquakes. Similarly, scientific communities need to know how to put scientific knowledge in mitigation perspective from the point of view of non-scientific communities. How do we bridge this gap? We at AIDMI acknowledged this gap, and from the overlapping questions, we selected four key areas relevant to Kashmir and South Asia and discussed them in this issue.

How do we use scientific knowledge on earthquakes?

Certain regions of South Asia are more vulnerable to earthquakes than others. Kashmir ranks high on this list. Fortunately, geologists know which regions are more vulnerable and why. When this information is disseminated to NGOs, relief agencies and governments, they can quickly understand where investments, attention and disaster preparedness measures should be focussed. Not everyone can, or needs to be targeted, and relief and recovery money should be invested wisely, based on informed decisions. Earthquake risk maps reveal which States need to pay more attention to the earthquake risk.

What are the scientific lessons from Kutch to Kashmir?

Kutch in Gujarat has had several destructive earthquakes over the last 200 years. Each has left a legacy not only of destruction but also of lessons that should have been learned. Sadly, most rebuilding measures have repeated the mistakes of the past.Earthquake history is full of information, which can be used by town planners, NGOs and communities rebuilding their structures. Town planners working in the aftermath of an earthquake can use the unique opportunity to rebuild the town in a safer manner: may it be Anjar, Islamabad, or Sri Nagar. For example, earthquake science informs us that not all locations within the vicinity of an earthquake experience the same magnitude of tremors. Thick sediments amplify these destructive effects, and thin sediments do not. Therefore, important buildings should not be built on thick sediments. Science also says that we should strengthen buildings against earthquakes. This can be done in the inexpensive ways, which have been researched by structural geologists and put to use in Kutch now for over three years.

Is earthquake all about the ground shaking?

Earthquake is not just about the ground shaking. There are many effects of an earthquake, which are not immediately apparent: 'surface rupture' (where the earthquake breaks the surface), liquefaction (ground loses strength to support buildings) and landslides are also part of the earthquake's destruction. Rehabilitation measures so often ignore this fact. Education is the key to mitigating the effects of an earthquake. Teaching people about these effects can help them in many ways: to construct buildings more safely, to protect themselves during and after the earthquake by being aware of dangerous areas.

Is earthquake forecasting a reliable science?

Many scientists are able to give detailed forecasts about earthquake risks in certain regions, which can help governments, NGOs and local communities focus resources at the correct time and in the correct locations. Gujarat has claimed to set up such a centre, now for over four years.

This issue of southasiadisasters.net tries to draw attention of humanitarian sector on scientific perspective of earthquake and bring them closer to scientific communities and their work in Kashmir. ■

Mihir R. Bhatt

Seismic Destruction: Why is Kashmir so Vulnerable?

It is clear to many people that India is especially prone to earthquakes and the various forms of destruction they cause, but it is not widely known why this is so. By looking at the history of India over millions of years, we can try to understand this phenomenon.

Why do earthquakes happen at all?

The tectonic plates

The earth's surface can be divided into a series of tectonic plates, which move slowly past each other at speeds of a few mm a year. Over millions of years, tectonic plates can travel thousands of kms. Earthquakes tend to occur at plate margins, where friction between the two plates means 100s of years' worth of accumulated plate movement is released in one devastating event. The interiors of tectonic plates tend to be stable, but in India it is a different story.

India's long history

The Indian sub-continental plate detached from the Gondwanaland super-continent 130 million years ago. 80 million years later it collided with Asia after moving thousands of kilometres across what is now the Indian Ocean. The Indian subcontinent is still moving north into China - at a speed of 50mm per year it is the fastest moving landmass on the planet.

The Himalayas

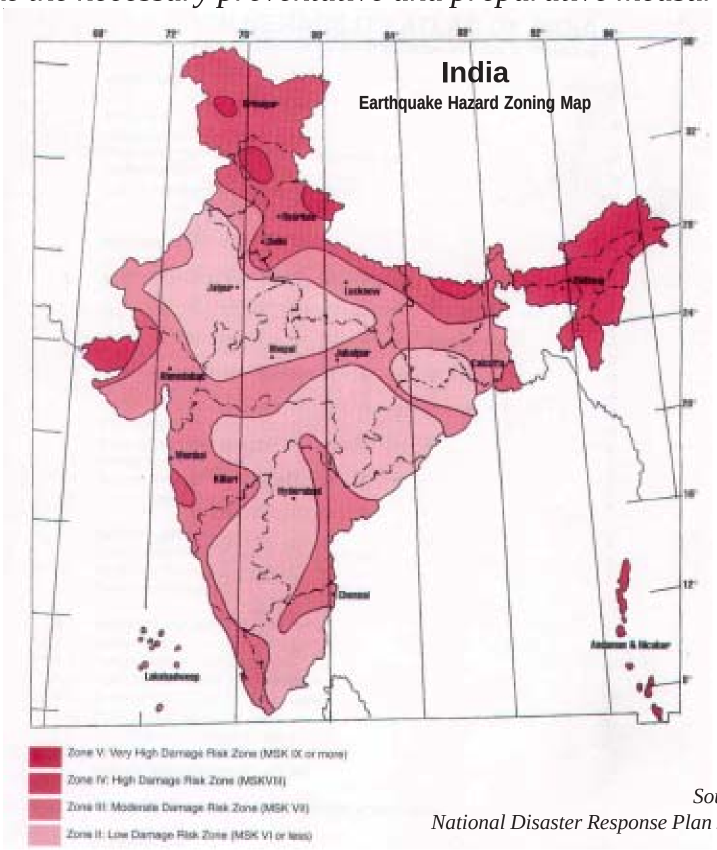
When two sections of continental crust collide, they crumple to build high mountains like the Himalayas. Such mountains are constantly growing, and earthquakes occur as the deforming zone grows outwards and the mountains fold internally. The Himalayas will always pose a massive earthquake risk, as they absorb most of the collision's energy.

Earthquakes in the continental interior

If all of the crust of the Indian subcontinent was the same strength, then earthquakes would only occur at plate boundaries, like the Himalayas. However, during India's long history, it has begun to break and crack along regions called failed rifts. While this did not result in a fragmented Indian continent, the faults formed between 200 million and 80 million years ago still exist in the Indian crust. The result is weak regions of the crust that break under the compressive stress of India's collision with Asia. Bands of seismic activity cut across India as ancient faults are reactivated. These bands are clearly visible in the earthquake hazard-zoning map below. The rift systems formed are especially important in Gujarat and western Rajasthan. ■

Which Parts of India are More Prone to Earthquakes?

It is possible to conduct seismic hazard assessments and produce maps indicating areas of high seismic risk. This allows governments of particularly vulnerable states to take the necessary preventative and preparative measures.



Source:
National Disaster Response Plan 2001

Gujarat's Long Earthquake History

We should not ignore what has passed before over the years. Gujarat's earthquake history can teach us many important lessons.

Kutch Peninsula History

The 2001 Bhuj earthquake occurred on the Kutch Peninsula, which has a long history of strong earthquakes (Figure 1). The region is bordered to the north and to the south by ancient rift systems. Faults within these rift systems and on the Kutch mainland are now subjected to compressional stress resulting from India's collision with Asia. Several destructive earthquakes have occurred in the Kutch region of Gujarat during the past two centuries, among them Allah Bund earthquake (M7.8) in 1819, Anjar earthquake (M6) in 1956 and the recent Bhuj earthquake (M7.6) in 2001. The Anjar earthquake was on KMF (Kutch Mainland Fault) and the recent Bhuj events were caused by a hidden fault north of KMF. Damaging earthquakes also occurred in 1845, 1856, 1857, 1864, 1903, 1927, 1940 and 1970 in the Kutch region but with less severity (5 < M < 6).

Tsunamis in Gujarat

The events of 1845 were felt in Karachi and are reputed to have generated a tsunami and to have caused changes in channel depth near and north of Lakhpat on the western edge of the Kutch Peninsula. No specific earthquakes in the Ahmedabad region exist in the historical record, however a large tsunami is reported to have occurred in 1524 that caused considerable alarm to the Portuguese fleet assembled offshore.

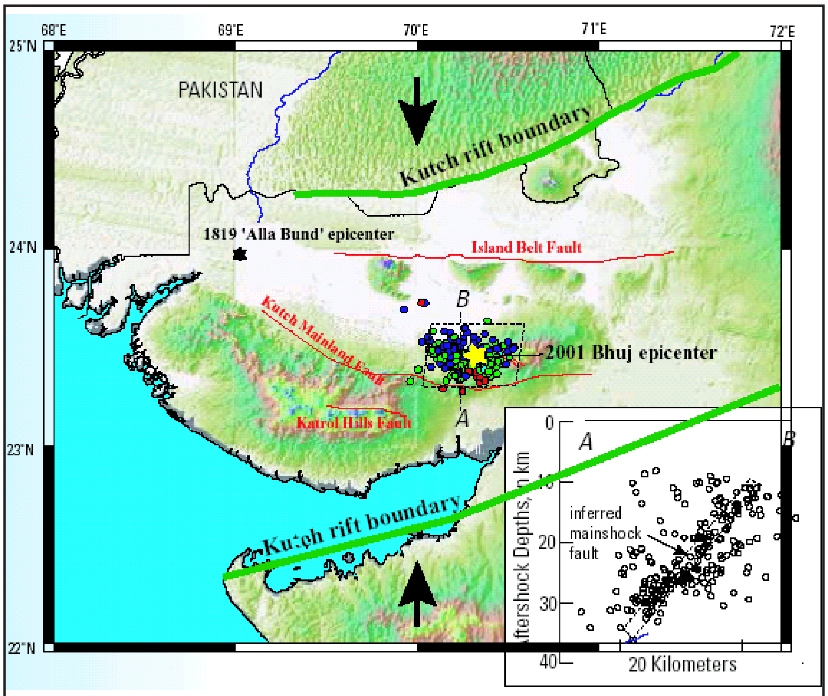


Figure 1. Shaded relief map of northwestern Gujarat, showing the 2001 Bhuj and the 1819 Alla Bund earthquakes.

Inset: Aftershocks viewed in cross-section, along a line from A to B, reveal a southward dipping fault.

Source: United States Geological Survey Fact Sheet FS-007-02 March 2002.

Damage in 1819

Damage to Bhuj and Anjar during the 1819 earthquake was substantial. Much like those from the 2001 event, damage reports from 1819 describe widespread collapse of structures on the Kutch mainland, accompanied by substantial liquefaction features in the Rann of Kutch.

Shaking Intensity Maps of the 2001 Earthquake

Although preliminary, the intensity maps (Figure 2) already show several interesting features. The event was felt only lightly at the higher-elevation cities throughout central and southern India. Away from the Kutch region, intensities were clearly amplified significantly in areas that are along rivers, within deltas, or on coastal alluvium, such as mudflats and saltpans. Significant site effects were observed within Mumbai. While most of the city experienced weak shaking, higher intensities were reached in areas built on landfill in southern and central Mumbai as well as along Bombay Harbour. Variations in the distribution of felt intensity are also apparent in the Kutch region. Significant sediment-induced amplification is suggested at a number of locations around the Gulf of Kutch, including Kandla and many of the villages on mudflats around the Gulf of Kutch. Liquefaction features produced in the Rann of Kutch included sand volcanoes and fissures that expelled enormous volumes of sediment, infilling broad river channels and spreading outwards as much as 3-5 km.

Lessons to be Learned

Many accounts of the 1819 earthquake drew attention to the relative immunity of structures on bedrock compared to those on sediments. A similar observation has been made in the 2001 Bhuj earthquake. It is clear that had this been included as a post-1819 earthquake reconstruction guideline, damage in many areas in 2001 would have been reduced. Since 1819 the population has increased by a factor of ten in Gujarat. In 1819, 2000 people were killed, and in 2001 close to 20,000. It is difficult to escape the grim observation that the same fraction of the Kutch population lost their lives in the two earthquakes. Yet the long-term legacy of the Bhuj earthquake need not only be one of tragedy if the seismological and earthquake engineering communities can exploit the available data to the fullest extent possible and make use of the lessons learned. ■

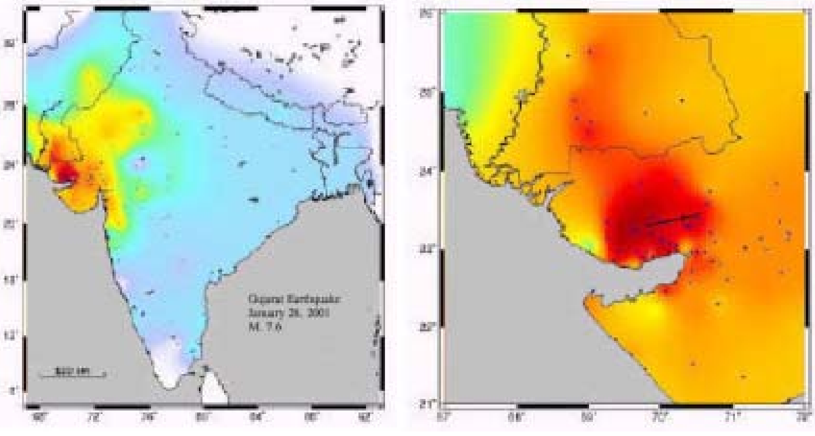


Figure 2. The distribution of intensities throughout Indian subcontinent is shown on the left; the intensity distribution in the Kutch region is shown on the right. The approximate location of the fault is indicated on the right (black line).

Source: Bendick, Bilham, Fielding, Gaur, Hough, Kier, Kulkarni, Martin, Mueller, Mulkul, Seismological Research letters, 2001.

Strengthening Buildings Against Earthquakes

The methods of protecting buildings against the destructive power of earthquakes can be inexpensive and simple, ideal for incorporating into the design of houses in large scale reconstruction projects in poor areas. The most common causes of building failure during earthquakes are:

- Structural layout
- Quality of materials and construction practices
- Lack of earthquake resistant features

Structural Layout

The building should be as symmetrical as possible. Lack of symmetry leads to torsional effects and adds to the concentrated damage in critical zones. Simple square or rectangular designed buildings survive earthquakes better. It is best if the building is not more than three times longer than its width, because damage is more concentrated in narrow sections. Separation of large buildings into well spaced separate parts is good practice to keep symmetry and regularity. The building should be kept as simple as possible - where ornamentation is used it should be securely anchored. The distribution of stiffness throughout the building should be as uniform as possible, and the locations of load bearing walls and reinforced concrete columns should not be shifted between stories. The floor height and number of stories should be limited according to the structural system and building materials. Opening, like doors and windows, are a source of weakness and should be carefully symmetrically positioned and at the same position in each storey, and should not interfere with any structural load-bearing elements.

Materials and Quality of Construction

Building materials can be classified as follows:

- Highly suitable: wood, steel, reinforced concrete
- Moderately suitable: reinforced bricks and blocks with good mortar,
- Slightly suitable: unreinforced bricks and blocks with good mortar
- Unsuitable: unreinforced masonry with mud mortar, earthen walls.

With proper reinforcements, however, brick, stone and timber can be the main materials for construction. The quality of construction practices in brickwork, stone masonry, block masonry and wood work has an undoubted influence on the extent of the earthquake damage. This can be more important than the materials themselves.

Earthquake Resistant Features

For improved integrity, buildings should have the following reinforcing features:

- Walls should be properly jointed together at junctions, and floor and roof components firmly bolted to each other and to the walls.
- Evenly spaced bands of reinforced concrete should run horizontally and vertically across plain walls, and around gable ends.
- Reinforced concrete should connect the roof to the walls so that during the earthquakes they move as one.
- Floors and roofs should be stiffened by horizontal bracing.■

What Controls the Strength of the Ground Shaking During an Earthquake?

Not all locations within the vicinity of the earthquake epicentre experience the same degree of ground shaking. Two main factors determine the strength of the shaking: the softness of the ground and the depth of sediment.

Why are Earthquakes so Destructive?
Most earthquake fatalities and damage occur when buildings and other structures fail during violent shaking caused by seismic waves, which travel through the ground from the rupturing fault like the ripples from a pebble dropped into a pond. The intensity of shaking depends on the quake magnitude (size of the pebble) and distance from the fault (ripples get smaller as they radiate outward). However, the radiation of seismic waves is much more complex than the steady progression of circular ripples in a pond. One reason is that the Earth's crust is not homogeneous like water, but rather a complex mixture of rocks and sediments of varying types that respond to shaking in different ways. In a single earthquake, the shaking at one site can easily be 10 times stronger than at a neighboring site, even when their distance from the ruptured fault is the same.

What Types of Location are Most Prone to Ground Shaking?
It is possible to quantify how levels of ground shaking are modified by various characteristics of local geology. The two factors found to be most important are the softness of the ground at a site and the total thickness of sediments below a site.

Softness of the ground:
Seismic waves travel faster through hard rocks than through softer rocks and sediments. As the waves pass from harder to softer rocks and slow down, they must get bigger in amplitude to carry the same amount of energy. Thus, shaking tends to be stronger at sites with softer surface layers, where seismic waves move more slowly.

Destruction in the aftermath of the 2001 Bhuj earthquake.

Source: AIDMI

Total thickness of sediments:
Sediment-filled valleys, with their relatively flat terrain and fertile soil, are attractive locations for human settlement. In an earthquake, however, as the thickness of sediment increases, so too does the amount of shaking. For example, shaking levels can double from the edge a basin, where the sediments are thin, to the middle of the basin, where sediments reach a thickness of more than 6 kilometers.

Variation in shaking patterns:
The two characteristics above can explain some, but not all, of the variations in earthquake shaking at specific sites. Computer simulations of how seismic waves travel outward from fault ruptures indicate that there will be "hotspots" of anomalous shaking unique to each earthquake. These hotspots depend on specific details of the earthquake, such as orientation of the fault, irregularities of the rupturing fault surface, and scattering of waves as they bounce off subsurface structures. Useful prediction of these effects would require comprehensive computer simulations of potential earthquakes on a case-by-case basis.

How can we use this knowledge?
It is important to recognise the danger of building on thick sediment. In some areas, where it cannot be avoided, where flat building land is scarce, communal buildings, such as schools and hospitals, should be built on bedrock. Buildings that have to be constructed on thick sediment should incorporate strict seismic safety measures. ■

Shaking, Slumping and Sliding: The Earthquake Effect

An earthquake's destructive power has many forms, but measures can be taken when constructing new structures to minimise the damage quakes cause.

Ground Shaking

Surface waves travel across the surface of the earth, outwards from the earthquake epicentre, moving the ground vertically and horizontally. These large amplitude waves comprise most of the destructive force of the earthquake. Deep soft soils and sediments amplify the shaking effects. Ground failure in the Bhuj region in Gujarat, following the January 2001 earthquake, most likely resulted from shaking, as the soil mass cracked and slid down the almost imperceptibly sloping ground surface.

Building Failure

The shaking loosens the joints of different components of a building; walls may move apart from each other and crack, heavy roofs collapse with the applied horizontal force, and smaller components, such as chimneys, balconies, roof tiles and plaster are dislodged and fall. The forces that occur in the building come from the inertia of its own mass; the heavier the building, the greater the earthquake effect. Structural engineers propose practical structural layouts and methods of strengthening building joints to help combat this effect.

Surface Rupture

A surface fault rupture occurs when an earthquake breaks the earth's surface; such ruptures cause localised but intense devastation. Structures bridging a rupture are destroyed; when earthquakes break the ground surface, the movement may be horizontal or vertical and the displacement may be a few centimetres or a several metres. Not all earthquakes cause a surface rupture; deep earthquakes, and earthquakes occurring beneath soft sediment are less likely to do so. Faulting associated with the 2001 Bhuj earthquake stopped far below the ground surface. Earthquakes tend to occur along, or very close to, existing fault lines, where rocks are weak. Evidence of a past surface rupture is a strong indication that there could be another such rupture close by. When building new structures it is important to study the tectonic map of the area and build at a reasonable distance from such threats. In Nepal new buildings are constructed at least 500m from the surface trace of an active fault.

Liquefaction

Liquefaction is a type of ground failure that occurs when saturated soil loses all its strength and collapses or becomes liquefied. The shaking causes the soils to compact, raising the water pressure and promoting liquefaction. It is more prominent if the foundation soil consists of uniform loose sands within about 8m of the ground surface and when the soil is either fully saturated or submerged by water. It commonly results in sand boils, fissuring of the ground and uneven resettlement of the ground surface. Buildings resting on such ground may tilt or sink and can collapse. In the Bhuj region, during the 2001 earthquake, there was widespread liquefaction.

Landslides

Earthquakes cause landslides where topography is potentially unstable. Such terrain occurs in areas of mountain growth, such as the Himalayas, where slopes are at the

Destruction in the aftermath of the 2001 Bhuj earthquake.

Source: AIDMI

maximum stability gradient, and in areas suffering storm damage, river undercutting and quarrying. All major earthquakes in steep terrain will result in increased instances of landslides, as the shaking dislodges otherwise stable ground features. Landslides occur in the form of rock falls, debris slides and soil slumps. Buildings may be destroyed by landslides either because they are located on the body of the landslide or because they are hit from debris from a landslide uphill from the site. The building itself may also contribute to the instability of the slope. Landslides may also occur after the earthquake during instances of high rainfall; the increased water pressure destabilises soils and rocks that have been displaced by the quake. Earthquakes are more likely to result in landslides during the wet season. ■

Is Earthquake Forecasting a Reliable Science?

While it is impossible to predict the date, magnitude and location of an impending earthquake, it is possible to make official warnings, giving the probability that an earthquake will happen within a certain time.

Earthquake Clusters:

Earthquake forecasts are based on the tendency of earthquakes to occur in clusters, within a limited time period. The largest earthquake in a cluster is called the mainshock, those before it are called foreshocks and those after it are called aftershocks.

Aftershocks

Aftershocks occur as the crust in the mainshock area shifts and resettles after the earthquake. An uneven fault-slip pattern due to localised areas of high friction on the fault surface and the formation of high-porosity-low-strength regions during the quake result in aftershocks; such tremors tend to be too small to cause much damage. However, they are the most numerous quakes in the cluster, and they act within areas already devastated by the mainshock. A moderately powerful aftershock can hamper the efforts of relief workers, and cause damage and casualties in an area deprived of basic amenities and struggling to recover survivors. By studying past earthquakes it is possible to detect patterns in the way that aftershocks decrease in number and magnitude with time. These patterns are used to produce aftershock forecasts that can assist governments, industry and relief workers and advise when it is safe to demolish, repair, or allow people to use damaged structures.

"Earthquake relief workers and the general public can use earthquake risk information to prepare for a forecast shock, to allow them to conduct rapid, well-planned responses."

Foreshocks

Some large earthquakes are preceded by foreshocks. Knowledge of past earthquakes patterns makes it possible to estimate the odds that an earthquake striking today is a foreshock and will be followed by a larger mainshock in the same area. These odds depend on the magnitude and type of earthquake and the seismic history of the fault on which it occurred. Such warnings have been issued in the quake-prone state of California, USA. ■

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