Abandoning Richter

How a white lie finally caught up with seismologists

By RICHARD MONASTERSKY

Seismologists, as a rule, tend to keep their cool, even when the ground heaves beneath their feet and buildings collapse around them. But these days, earthquake experts are scurrying for cover at the mere mention of two words. Such is the fallout over use of the term "Richter scale" — a household phrase that lies at the heart of a brewing controversy about conveying earthquake information to the public.

The rhetoric has reached such a pitch that one newspaper columnist pilloried the agency in charge of disseminating earthquake information. "A kick in the butt is what someone ought to give the U.S. Geological Survey for its dithering about how to define the magnitude of earthquakes," wrote Keay Davidson in the San Francisco Examiner following a large Bolivian tremor on June 8.

Davidson is by no means alone. Reporters, editors, and many seismically sensitive members of the public are having trouble sorting out how scientists measure earthquakes. Much to their dismay, people are learning that seismologists typically do not use the Richter scale to judge quake size.

It's almost like hearing that Santa Claus doesn't exist.

"What's going on is that we're just recovering from decades of telling a white lie, that's all," says seismologist Thomas H. Heaton half in jest. Heaton is president of the Seismological Society of America and a USGS researcher in Pasadena, Calif.

In one sense, the flap boils down to semantics. While seismologists generally do not use the original Richter magnitude scale, the measuring systems currently in vogue represent extensions of the type that Charles Richter developed nearly 60 years ago. That explains why some seismologists continue to use the term when addressing the press.

But the recent brouhaha goes beyond the question of the name itself. According to seismologists who frequently get up in front of the television cameras, the problems now surfacing reflect a deep-seated misunderstanding about earthquakes — one that has important consequences for how the public and even engineers respond to seismic hazards.

"The public gets extremely confused after they've been through a heavy shake, and they're frightened," says Heaton. "Then you say, 'Oh, by the way, we're expecting an 8 and that is 50 times bigger.' What they now imagine is 50 times the intensity of the ground motion they just felt, and they realize that nothing can survive it. At that point, they just stop talking about it."

Frequency of earthquake occurrence, based on observations since 1900

Descriptor	Magnitude	Annual Average
Great	8 and higher	1
Major	7-7.9	18
Strong	6-6.9	120
Moderate	5-5.9	800
Light	4-4.9	6,200 (estimated)
Minor	3-3.9	49,000 (estimated)
Very minor	less than 3.0	Mag. 2-3: about 1,000/day Mag. 1-2: about 8,000/day

Source: USGS

It's only fitting that Davidson and other reporters feel such a strong connection to the Richter scale, because journalists played an important role in its origin. "[Richter] introduced it because he was tired of the newsman asking him about the relative size of earthquakes," recalls veteran seismologist Bruce A. Bolt from the University of California, Berkeley.

Prior to Richter's work, researchers in the United States had no way of judging an earthquake's absolute size, which remains the same no matter where it is measured. Instead, they dealt with a concept called intensity, which describes the strength of shaking at a particular location. Because tremors fade with distance from the epicenter, the intensity of a single quake varies considerably from point to point.

In the early 1930s, Japanese seismologist Kiyoo Wadati devised a method of comparing the sizes of quakes. He would take seismic recordings of various shocks and set them on an equal footing by factoring in the distance between the recording station and the earthquake.

But this method was not easily grasped by lay people, especially the reporters of quake-plagued southern California. In 1935, Richter dressed up the Japanese method to create an earthquake index — a simple numerical scale much like the stellar magnitudes used by his astronomical colleagues at the California Institute of Technology in Pasadena. Richter defined seismic magnitude in terms of a particular type of recording device, called a Wood-Anderson seismograph, situated at a standard distance of 100 kilometers from an earthquake's epicenter.

Richter also appropriated from astronomy the idea of a logarithmic scale — based on powers of 10 — to accommodate the incredible range of earthquake sizes. (The smallest detectable tremors equal the energy of a brick dropped off a table, while monster quakes surpass the largest nuclear explosions.) By Richter's original definition, a shake of magnitude 1.0 would cause the arm of the Wood-Anderson machine to swing one-thousandth of a millimeter. A magnitude 2.0 temblor would make the arm swing 10 times as much, or one-hundredth of a millimeter.

In theory, the scale had no upper limit. But in practice, magnitudes could not top 7.0. "You would never see an earthquake bigger than magnitude 7 [on the original magnitude scale], or at least we hope you never would because everything would be dead," Heaton says.

Of course, scientists rarely had a Wood-Anderson seismograph stationed exactly 100 kilometers from an earthquake. But by comparing the arrival of slow versus fast seismic waves at a recording station, they could calculate what one of the devices would have detected at the standard distance.

The magnitude index, as originally

defined, could only measure southern California earthquakes because Richter calibrated the scale for the crust there. What's more, it only worked for jolts within a few hundred kilometers of a Wood-Anderson seismometer.

Recognizing these limitations, Caltech's Beno Gutenberg and Richter devised a more general magnitude measurement to handle distant earthquakes. To avoid confusion, they denoted the new magnitude M_S, because it depended on measurements of surface waves rippling through Earth's crust with a period of about 20 seconds. The original magnitude scale — based on waves with periods of 0.1 to 3.0 seconds — became known as M_L, or local magnitude.

Even the new and improved magnitude formula had problems, however, because deep earthquakes do not produce many surface waves. So Gutenberg and Richter invented m_b, measured from body waves, which travel through the planet's interior. This yardstick proved helpful in distinguishing nuclear explosions from actual earthquakes.

In the 1970s, seismologists realized that all existing magnitude methods underestimated the energy of truly large earthquakes. To circumvent this limitation, Hiroo Kanamori, a successor of Richter and Gutenberg at Caltech, created a magnitude scale, M_W, that quantifies the total amount of seismic wave energy released in an earthquake.

But because such calculations are difficult, scientists usually approximate the energy by computing a quantity called "seismic moment," determined from long-period vibrations. In the case of great earthquakes, these vibrations have cycles longer than 200 seconds. Seismologists therefore refer to M_W as the moment magnitude.

M_W differs from all other types of magnitude in that it measures the earthquake source, Kanamori says. The Richter magnitude and most others gauge only the strength of vibrations sensed at Earth's surface. But to calculate moment magnitude, seismologists use the long-period waves to decipher the dimensions of the fault rupture that produced the quake.

In other words, moment magnitude measures the cause rather than the effect.

Although researchers have developed more than a dozen other ways of calculating earthquake magnitude, moment magnitude remains the figure of choice among seismologists, especially for earthquakes larger than magnitude 6.5.

Confused?

With M_L, M_S, m_b, M_W and a litany of other Ms floating around, it's no wonder that many seismologists took the easy way out over the years by giving reporters what they thought the media wanted. When pressed for details, researchers typically simplified the issue by calling any magnitude a Richter magnitude, even though this term applies only to the local magnitudes determined by Richter's original formulation.

"The problem is that seismologists have used the term 'Richter scale' in a very loose way, and now it's catching up with them. We didn't use it among ourselves because it doesn't mean anything," Heaton says.

These days, seismologists hope to clean up the magnitude morass in their dealings with the public. The USGS put out a statement in July explaining how the newer measurements do not renounce the Richter scale but rather extend the original magnitude both to greater distances and to larger earthquakes.

At the USGS' National Earthquake Information Center in Golden, Colo., director Waverly J. Person says his staff balances the need for timelines with the desire to report moment magnitudes, which take an hour or two to compute.

Immediately after an earthquake, the center releases a preliminary measurement, which could be a surface wave magnitude, a body wave magnitude, or even a local magnitude (similar to Richter's original formulation except that modern seismographs have replaced Wood-Anderson ones.) After determining the moment magnitude, they release this number, which may fall above or below the preliminary one.

As for the use of the term "Richter scale," the USGS has dodged any decision. "The question of labeling these magnitudes as 'Richter scale' is a matter of tradition, semantics, and personal perspective. The USGS has no official scientific position on the use of the term," declares the July statement.

The USGS' Heaton, who works across the street from Richter's old Pasadena

Sizing up seismicity

When Charles Richter invented the concept of seismic magnitude, he made it easy to compare earthquakes. Anyone who can count to 10 will recognize that a magnitude 7.0 shock packs a bigger punch than a 6.0 quake. But the question "How much bigger?" is not so easily answered.

In the original definition of magnitude, a 1-point increase meant that peak waves recorded by a Wood-Anderson seismometer jumped by a factor of 10. So far, so good. But not all seismometers respond to seismic waves equally. Some measure different frequencies, and some are more sensitive than others. So newer instruments do not respond the way Wood-Andersons did in their era.

Delving even deeper, what does the seismometer measure anyway? It doesn't translate directly into the strength of the shaking felt by humans or buildings, because seismometers measure one band of frequencies, whereas we feel a different range of waves.

An increase of one unit in magnitude therefore does not translate cleanly to 10 times more shaking. In fact, the force of the ground motion close to a tremor's epicenter rises much less than a factor of 10.

Going from a magnitude 6.5 to 7.5 jolt, the jerky shaking close to the quake may increase in strength only by a factor of 1.5 (equal to a 50 percent boost). On the other hand, a seismograph stationed halfway around the globe may measure a 10-fold difference in the surface waves that have managed to travel that far.

In terms of energy, magnitude units rise even faster. A step of one full unit increases the energy by roughly 33 times, so a magnitude 7.0 quake unleashes approximately 1,000 times the energy released by a magnitude 5.0 temblor.

Is there an easier way? Some feel that the logarithmic magnitude scale is just too difficult for the public to comprehend. "It's made a lot of confusion," says Thomas H. Heaton, president of the Seismological Society of America. "To be honest, I think Richter did us a disservice. We spend as much time explaining to the public what a logarithm is as anything else. We could have just given them a number in the first place and not bothered with a logarithm. Why not just say 1, 10, and 10 million."

Seismologists themselves compare earthquakes using seismic moments, which represent the length of the fault rupture multiplied by the amount of rock movement and then again by the stiffness of the rock. But moments are expressed in unwieldy numbers, such as 2×10^{27} newton meters — clearly not an appealing figure for the public.

Pat Jorgenson, a USGS spokeswoman in Menlo Park, Calif., says she would prefer to discuss quakes in terms of something people can comprehend. "When the comet hit Jupiter this summer, it was reported that this was equivalent to so many atomic bombs. Why can't we report earthquakes like that?"

In that vein, a magnitude 1.0 earthquake would equal roughly 6 ounces of TNT. For a magnitude 5.0, think of 1,000 tons of TNT. A quake of magnitude 7.2 corresponds to a million tons of explosive — which is a little less than the energy locked in the swirling winds of a typical hurricane. The largest recorded earthquake, of moment magnitude 9.5 in Chile in 1960, equaled about 3 billion tons of TNT. *— R. Monastersky* office, says he wants to avoid the term entirely. "You probably wouldn't catch us using the term 'Richter magnitude' around here, even though this was the home of Richter."

Other seismologists note that while the public feels comfortable with the term, they often lack even a basic understanding of what it means. Several scientists tell tales of people asking to see the Richter scale.

"It seems to be a popular misconception that it's actually a piece of equipment, like a bathroom scale," says Roger Musson of the British Geological Survey in Edinburgh. "Things have come to such a pass in today's press that I had an inquiry recently from the Sunday Times, no less, asking for a picture of the Richter scale. I said this was a bit like asking for a picture of kilometers."

Others describe the wild rumors that circulate after an earthquake. In the case of the Jan. 17 Northridge, Calif., jolt, the reports of different earthquake magnitudes — M_S 6.6 versus M_W 6.7 — confused many Angelenos, prompting speculation that the USGS was underestimating the magnitude to save the federal government from spending disaster relief money.

"People thought we were lying on the magnitude," says an incredulous Heaton.

As journalists get more seismically sophisticated, they may head off some of the confusion. The Associated Press recently retired the term "Richter scale" in favor of the phrases "preliminary magnitude" and "moment magnitude." Unless further elaboration is required, SCIENCE NEWS will continue its tradition of using the generic word "magnitude," which in the case of recent earthquakes refers to a determination of moment magnitude.

But simply tidying the terminology will not, on its own, help people better understand the size of an earthquake. After all, how can one number convey the power of something equivalent to a colossal nuclear explosion?

Even moment magnitude does not suffice, says its inventor. "The problem is everyone thinks that a single number determines everything. It's almost like asking how big you are," says Kanamori. "The question is whether you are asking height, weight, or width. Depending on how you measure a person, the answer can be very different. In the case of earthquakes, it's even more complex." □

Quakes and their equivalents

Magnitude	Energy Released (in millions of ergs)	Rough Equivalent
-2	630	100-watt lightbulb left on for a week
0	630,000	1-ton car going 25 miles per hour
2	630,000,000	Amount of energy in a lightning bolt
4	630,000,000,000	Seismic waves from 1 kiloton of explosives
6	630,000,000,000,000	Hiroshima atomic bomb
8	630,000,000,000,000,000	1980 eruption of Mount St. Helens Largest recorded quake, M_W 9.5, Chile, 1960
10	630,000,000,000,000,000,000	Annual U.S. energy consumption

Science & Society

Gulf War syndrome research boosted

In late September, President Clinton signed legislation providing a substantial increase in funding for research on the possible causes of and cures for Gulf War syndrome, the mysterious illness afflicting military personnel who served in the 1991 Gulf War and some of their family members.

Legislators are also debating how to provide compensation to the ill veterans.

The Department of Defense's fiscal year 1995 appropriation includes $8.4 million for Gulf War syndrome research. Last year, lawmakers appropriated $1.9 million for this work.

Most of the fiscal 1994 and over a third of the fiscal 1995 monies are earmarked for one Louisiana-based treatment study that DOD reviewers have yet to approve for funding.

So far, the odd array of symptoms associated with the syndrome, including debilitating fatigue, diarrhea, and sensitivity to chemicals, has defied diagnosis (SN: 6/18/94, p.94). Yet without a diagnosis for their illness, veterans do not qualify for medical compensation from the government.

The DOD bill allocates $5 million for peer-reviewed research by nongovernment scientists, including epidemiological surveys of Gulf War military personnel and their families.

Legislators direct that the remaining $3.4 million support ongoing research on an "antibacterial treatment method," which they describe in detail without naming the researcher doing the work. That researcher is physician Edward S. Hyman at the Touro Infirmary in New Orleans, congressional and DOD staff say.

Hyman testified last summer at a congressional hearing about his treatment for Gulf War syndrome. A panel of scientists is now reviewing a research proposal he submitted to DOD, says Chuck Dasey, an agency spokesman. If the panel approves the proposal, Hyman would receive almost $5 million, which includes funds held over from 1994.

Many sick veterans suffer from either superinfection with streptococci or infection with an unusual strain of these bacteria, Hyman told SCIENCE NEWS. Standard laboratory tests don't detect the bacteria's presence, but he uses a unique microscopic technique that reveals the organisms, he says.

He prescribes large doses of antibiotics to his patients and recommends that they take the drugs for at least a year after they feel better, he says.

Hyman has treated eight Gulf War veterans and six family members of ill veterans. "All have had beautiful responses," he says. Four patients relapsed, but two of those have since recovered. The other two are no longer under his care.

While the House, Senate, and Clinton administration support the need to compensate ailing Gulf War military personnel, as of last week they had yet to agree on how to provide such funds.

A Senate bill calls on the Department of Veterans Affairs (VA) to change its rules so that veterans with Gulf War syndrome would be eligible for compensation, a move the VA opposes. A bill in the House, supported by the administration, would authorize payments to ill veterans without the VA rule change.

The Senate legislation would also require the VA to analyze the health of children and spouses of ill Gulf War personnel. Normally, the VA neither monitors nor treats family members.

In July, the VA provided more than $1.5 million to three of its research centers to study the possible health effects of environmental contaminants present during the Gulf War.