SETTLEMENT AND CHANGE IN 'BASAL ZONE ECOTONES':
AN INTERPRETATION OF THE GEOGRAPHY OF EARTHQUAKE RISK[1]

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Introductory Remarks: Disaster Geography

The geography of disaster presents severe problems of interpretation as of practical response. Not least is the complex way both discontinuities and continuities of material life are involved. There is not only the disarray, uncertainty and destablisation that the disaster event itself is most widely typified by. Also there is always a carry-over of some stable features, or definite expectations; behaviors, struggles to restore an implied 'norm', that link disaster strongly to the rest of life, and the on-going patterns of its spatial organization.

In the present discussion I shall be concerned primarily with aspects of human geography that do express spatial continuities, asking how they may exercise an influence upon the location, form and recurrence of earthquake disaster. This seems to be the function of a human ecology of risk. That is to say, we shall look at the incidence and features of disasters as they relate to the habitats where they occur, the human occupancy of those habitats, and larger spatial continuities of socio-economic organization. Little will be said about the seismic issues or crisis behavior. If so much had not already been written about them this would lead to an unbalanced approach. But here we shall look essentially at earth surface features rather than seismicity; at the phenomena of human settlement and on-going relations to habitat rather than of crisis.

This is a frankly academic piece of work exploring such data and ideas as are available, rather than an attempt to guide policy or management. It will differ too in the balance of abstraction and concreteness from so much of the specialized work on seismic risk [UNESCO, 1978]. I would argue, however, that the matters discussed are essential parts of the realities of place and people into which earthquake-triggered disaster intrudes; with which relief efforts must cope, and with whose features any successful aseismic planning must ultimately deal.

First, we shall examine some of the geographical relations of the global distribution of damaging earthquakes in recent decades. This will be based upon an inventory of some 154 of the largest disasters for the last thirty years (Figure 1). It has rarely been possible to get sufficient evidence to place all examples in terms of the aspects discussed [Hewitt, 1978]. We shall then turn to more detailed locational, site and internal patterns of individual disasters.

The Global Distribution of Earthquake Disaster

Among the geoecological conditions that seem as significant as seismicity itself, and important determinants of the variation of risk within seismic zones, are terrain and climate.

The great majority of destructive earthquakes involve damage zones partly or wholly within mountainous terrain. In our inventory at least 90 per cent included areas of highly accidented topography, where available relief exceeds 1000m. In most instances for which we have relevant data, the damage zones also stretch over a range of those marked altitudinal and aspectual differences in climate and vegetation cover, typical of mountain ecosystems [Hewitt, 1972].

The role of mountain terrain in disaster cannot be reduced simply to the geophysical coincidence between mountain building and seismicity. Descriptions of the disasters show clearly how the form and degree of damages reflect the environmental peculiarities of mountain habitats. The significance of surface geology, topography and plant cover is demonstrated by the growing body of work on seismic microzoning [Brabb, 1979]. The 1974 Himalayan disaster described elsewhere [Hewitt, 1976] is a fairly extreme reflection of the significance of mountain conditions, but the large role of landslides, of adverse weather and difficulties of relief and communication in steep-slope terrain are repeated in many examples. I have discussed elsewhere the detailed ways mountain conditions shape the spatial patterns within disaster zones, so that the same problems for survivors, relief efforts and rehabilitation constantly recur [Hewitt, 1978].

The relations of globally common earthquake damage to mountain conditions will hardly surprise anyone familiar with mountain ecosystems, and the kinds of impacts earthquakes can have. However, there is an apparent global relationship to climate that is more paradoxical.

About three-quarters of the disasters in our thirty-year inventory occurred where regional climates are semi-arid or seasonally dry (Table 1, Figure 2, Appendix A). The main exceptions lie in the humid, mountainous islands of Southeast Asia. Even here, we are dealing mainly with climates that are "transitional," usually monsoonal with a marked seasonality, and with a variability shown by two or more "year-climates," to use Mizukoshi's terminology [1971].

The Budyko-Lettau Dryness Ratio, said to be a more sensitive indicator of biophysical conditions, [Lettau, 1969] was estimated for

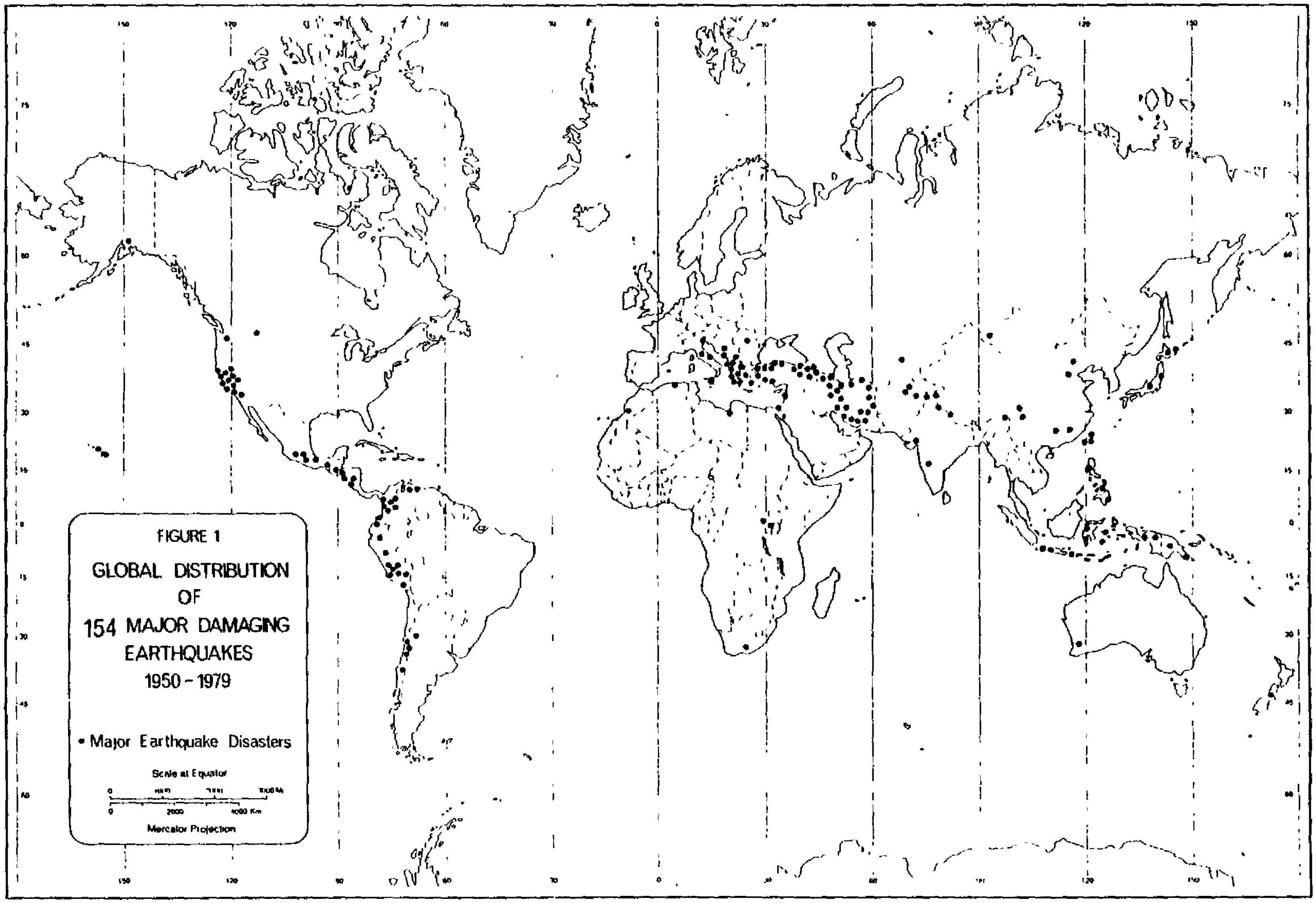


FIGURE 1

GLOBAL DISTRIBUTION OF 154 MAJOR DAMAGING EARTHQUAKES 1950 - 1979

¹ Outline Map Series Cartographic Centre Environmental Studies University of Waterloo Canada

the disaster areas too (Table 1). Mountain influences and remoteness from weather observations limit the accuracy of these estimates, but they do provide a striking indication of the regional association of most damaging earthquakes with zones of moisture stress.

More specifically, the disasters seem to be associated with zones of transition in moisture supply; that is, not simply in semi-arid or sub-humid areas, but where there are relatively marked gradients between drier and wetter zones. The seasonal precipitation is associated with seasonal shifting of storm belts. The important fraction of disasters occurring on or close to sea coasts involves strong gradients of moisture supply from the coast, inland. The orographic effect upon precipitation and rain shadows further create sharp moisture gradients across these areas.

There is an anomalously high concentration of disasters in "humid mesothermal" climates with a marked summer dry season. Nearly thirty per cent occurred in Koppen's class Csa, the 'mediterranean' and 'sub-mediterranean' climates [Aschmann, 1973a].

Now, the geography of seismicity itself shows no relationship to climate, and no known causal connection exists between the two. Therefore, if the evidence of recent disasters does show a higher concentration in particular climates, this must have to do with influences of surface conditions upon the impact of seismic shocks. That may be in direct physical ways such as the effects of geoecological conditions upon, say, slope stability. Or they may depend upon the nature of human settlement, or more likely, the interaction of the two to produce a greater vulnerability in these habitats.

Evidence of Human Ingredients of the Global Distribution

Wherever one can obtain local details of damage and of pre-disaster conditions for the earthquake areas, invariably they record more or less drastic, recent and accelerating processes of environmental and social change. The details are not simple or uniform. I have found no attempts to systematically record these features of earthquake disaster zones.

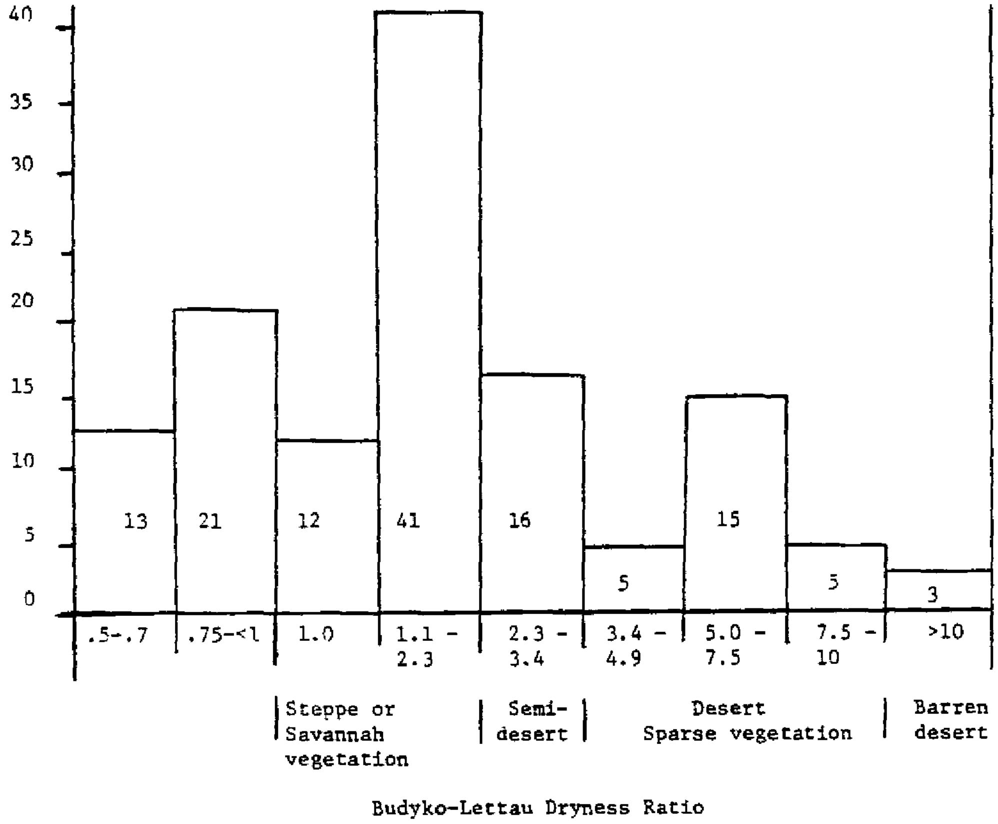
The most common of all observations relate to "poor construction" that includes new and old buildings; "traditional" and modern styles, poor design, poor maintenance, poor siting. What concerns the social scientist, however, is not just classifying what is damaged and what survives. We need to identify the processes, or indicators of processes, governing say, the proliferation of some types of structures when others might serve.

In the Himalayan disaster described elsewhere [Hewitt, 1976] much loss of life was due to the collapse of "traditional" buildings. But the few modern structures rarely stood up any better. Meanwhile, there were styles of "traditional" house or facility that resisted damage best of all (c.f. photos in Ambraseys, et al.,[1975]). More to the point, so many of the traditional buildings that failed were of relatively recent construction and in a style distinguished by lack of timber supports in the walls. There is reason to think this reflects a timber shortage. That style of building in the past was restricted to

Table 1

Regional Climatic Relations of Major Earthquake Disasters
(Jan. 1, 1950 - Dec. 31, 1979)
Provisional Site Classifications Using the Köppen System

Groups of Climate	Types of Climate		No. of Disasters
A. Tropical rainy	Af,	tropical wet	9
	Am,	tropical wet, monsoonal	9
	Aw,	tropical wet and dry	11
			29
B. Dry	BS, semi-arid (steppe)		
	BSh	tropical - subtropical, short moist season	12
	BSk	middle latitude meager rainfall, most in summer	9
	BW, arid (desert - constantly dry)		
	BWh	tropical and subtropical	6
	BWk	middle latitude	4
			31
C. Humid mesothermal	Dry summer, winter rain		
	Csa	Subtropical, hot summer ("Mediterranean")	33
	Csb	warm summer	9
	Dry winter		
	Cw		14
	Cwa	moist, warm summer	3
	Cwb	(Cooler than Cwa)	3
	No marked dry season		
	Cfa	humid subtropical	4
	Cfb	(cooler than Cfa)	9
			74
D. Humid microthermal	Dry winter		
	Dwb		1
	No marked dry season		
	Dfb	humid continental, cool summer	6
	Dfc	cold winter	2
			9
		Total	143



Notes: i) The Ratio (D) is: D = R/LP
where R = mean annual net radiation
P = mean annual precipitation
L = latent heat of vaporization of water
i.e. D >1 indicates an increasingly large moisture deficit.

ii) Of the sites having D.I <1.0, there are 23 with a marked dry season, and probably a net moisture deficit in some or most years. The majority are in monsoonal regimes of a transitional type (ed. Yoshino,

iii) "Desertification" has been most commonly recognised in areas with D between 2 and 7 (see Hare, 1976).

iv) Values for our sites were interpolated from maps kindly supplied by Prof. Dieter Henning of the Meteorological Institute in Bonn.

Figure 2

Distribution of Budyko-Lettau Dryness Radio for Major Earthquake Disaster Sites 1950-1979 temporary summer settlements at higher altitudes, animal shelters and poorer landless folk. Traditional designs that did have timber supports survived largely intact. The exceptions that I saw were cases where rotten beams failed, suggesting that the timber shortage had prevented renovations. Then again, the bulk of the losses and damage were due to slope failure and landslides. In most cases these occurred on recently deforested slopes. The remaining forested areas showed no evidence of the many rockfalls and soil slips on bare slopes. It seems fair to say that not only most of the damage, but the occurrence of a disaster at all was largely an artifact of recent land-use and socio-economic changes. The main ingredient of risk turned out to be man-induced destabilization of slopes fatally connected with impoverishment of traditional building supplies, when there has been little penetration of new techniques of sound construction. The single greatest source of damaging response to earthquake appears, therefore, as deforestation. In turn, this has surely been associated with progressively larger influences by outside social changes. They range from the role of medicine in increased populations or pressures to extend cultivated land, to economic incentives to expand the size of goat and cattle herds, and export lumber or firewood to the cities of the plains. One might just as well classify this as a 'development' or 'deforestation' disaster!

If Indus Kohistan has unique environmental and social conditions, similar transformations recur as background in the reports from most of the mountain area disasters. The literature is full of comments that suggest enhanced risk, --less often, decreased risk,-- as a result variously of development or "underdevelopment." In the latter there is often a greater transformation of land and people. In one area, rapid intensification of land use may be the issue; in another decline, impoverishment, or abandonment and increased out-migration.

Urbanization is a widely reported aspect of damages that reflect recent land use changes. Some of the more spectacular losses have been in new multi-story construction. Examples have been described in the disasters at:

Agadir, Morocco	1960
Niigata, Japan	1964
Alaska, U.S.A.	1964
Caracas, Venezuela	1967
Bucharest, Rumania	1977
Al Asnam, Algeria	1980

Elsewhere, and more extensive in numbers of structures involved, we find new wealth put into renovating older buildings, but in cosmetic ways that do not help, and may decrease structural safety [Ambraseys, 1976]. This has been remarked upon in several eastern Mediterranean disaster areas:

Fruili, Italy	1976
Thessaloniki, Greece	1978
Montenegro, Yugoslavia	1979
Al Asnam, Algeria	1980

But perhaps the most extensive problems and human misery relate to concentrated destruction in sprawling areas of new, poor housing and squattments. So often, they are on the poorest sites, whether steep hillsides, low-lying alluvial land, ravines and bluffs:

San Salvador, El Salvador	1965
Lima, Peru	1966, 1974
Luzon I, Philippines	1968
Managua, Nicaragua	1972
Guatemala City, Guatemala	1976

But an equal or perhaps larger aspect of this problem, is where older sections of cities are run-down, often they have become slums that modernization passes by. Here, even once solid buildings are weakened by neglect and decay to become death traps in relatively moderate earthquakes. In so many of the high risk areas of the eastern Mediterranean lands, for example, one can literally smell the dampness that betokens decaying masonry, stone, plaster, wooden beams. The results were seen recently in Kotor, Yugoslavia (1979) and in Naples, Salerno and the Campagnan mountain towns (1980). Similar problems were present in:

Cuzco, Peru	1950
Ionian Islands towns, Greece	1953
Arequipa, Peru	1960
Skopje, Yugoslavia	1963
Peloponnese, Greece	1965, 1966
Peru, Ecuador	1970
Fruili, Italy	1974

It may be noted, too,that if a high proportion of the worst events in recent years in terms of fatalities and property loss have been centered on, if not exclusively in, a large city, they do not necessarily involve the larger earthquakes (Table 2). How far that is a matter of the location of epicenters, or the kinds of sites the cities include and how far a problem of the urbanization itself, is not readily determined from the evidence available, but is a significant question given the pace of the process.

However, there is a much higher spatial probability that disaster will occur in the rural and small settlements that cover so much more of the habitable earth surface. And it is change, development and devolution beyond the urbanized areas that is the most widely reported transformation of all.

Rural "decline" or impoverishment, even in the presence of rapidly expanding populations and total productivity, recur in the landscapes of the many disasters in the interior of Turkey and Iran, as in Peru, Ecuador, Colombia and Mexico. It was equally apparent in:

Table 2

Features of Selected Damage to Urban Centers in Mountain Regions, from Earthquakes of Moderate Strength (c.f. Appendix A)

Place	Date	Richter	Casualties	Dollar loss estimates
Amato (Ecuador)	1949	6.8	6,000	66 million
El Asnam (Algeria)	1954	6.8	1,250	-
Agadir (Morocco)	1960	5.6	12,000	500 million
Skopje (Jugoslavia)	1963	5.8	1,200	1500 million
Caracas (Venezuela)	1967	6.5	277	150 million
San Fernando (California)	1971	6.6	64	750 million
Managua (Nicaragua)	1972	6.2	5,000	1000 million
Gemona de Friuli (Italy)	1976	6.5	965	2500 million

Assam, India-Tibet	1950
Ionian Islands, Greece	1953
Pindhos Mountains, Greece	1954, 1960, 1967
Chouf, Lebanon	1956
Barce, Libya	1965
Kashmir, N.W. India	1963, 1975
Peloponnese, Greece	1965, 1966
Western Nepal	1966
W. Sicily, Italy	1968
Celebes, Indonesia	1969
Pattan, Pakistan	1974
Fruili, Italy	1976
Irian Ja Ja, Indonesia	1976
Campagna, Italy	1980

In terms of our earlier points about mountain habitats, a further growing form of economic loss involves damaged installations related to recent accelerating development of resources and facilities in mountain areas. The Karakoram Highway, still under construction when the 1974 Himalayan disaster occurred, surely absorbed the bulk of the relief manpower in efforts to restore it for communication to and beyond the disaster zone. Elsewhere, damages to rail and highway links are widespread. To them are added destruction of tunnels, water conduits, dams, power lines, mining and forest operations. Common, but often given little attention is the fate of steep slope and terraced agriculture [Hewitt, 1976], sometimes in the process of abandonment but for the most part extending onto less stable areas. Examples of such damages related to economic and technological developments of mountain lands were found in:

Assam, India-Tibet	1950
Potesi, Nicaragua	1951
Kern Co., California	1952
Chile	1958, 1960, 1965, 1971
Mindanao, Philippines	1955
Elburz Mountains, Iran	1957
Hegben Lake, Montana, U.S.A.	1959
Alaska, U.S.A.	1964
Celebes, Indonesia	1965
Tashkent, U.S.S.R.	1966
Keyna, India	1967
N. Honshu, Japan	1968
Inangahua, New Zealand	1968
Peru	1970
San Fernando Valley, California, U.S.A.	1971
Hokkaido, Japan	1973
Khulm, Afghanistan	1976
Friuli, Italy	1976
San Juan, Argentina	1977
Montenegro, Yugoslavia	1979
Jiangsu Prov., China	1979

Of particular note, in relation to dryness of the regional environments are the many occasions when water resource facilities suffer destruction. Examples range from conduits in Maipo Valley, Chile (1958) and dams in the San Fernando Valley (1971), or Valparaiso Province, Chile, (1965); to irrigation ditches widely damaged in the Indus Kohistan disaster (1974) and Qanats in Iranian examples such as Turud, (1953) and Tabas e Golshan, (1978).

One final particular of damages relates to the great number of disaster zones that include sea coasts. Tsunamis are a notorious side-effect of seismicity that damage shoreline installations and fisheries. But of note lately are the number of occasions when port and harbour installations have suffered directly from shaking. And so often they prove to have been built upon alluvial deposits or artificial fill, flat land being so scarce along mountainous coastlines:

Long Beach, California	1951, 1955
Aegean Islands, Greece	1956
Chile	1960
Alaska, U.S.A.	1964
Niigata, Japan	1964
Lima-Callao, Peru	1966, 1974
Venezuela	1967
N. Honshu, Japan	1968
Manila, Philippines	1968
New Guinea	1970
Hilo, Hawaii	1973
Esmeraldas, Ecuador	1976
Montenegro, Yugoslavia	1979
Tumaco, Colombia	1979

A much-needed survey is that of the social circumstances of victims and survivors of these disasters. It is a vexed problem. Clearly, in most instances it is the relatively poorer, less vocal, powerless elements of society who suffer the greater casualties. It is equally obvious that they are most often the occupants of the least safe sites, of the least cared-for, most cheaply built or dilapidated structures, and therefore most adversely associated with the kinds of physical circumstances described above.

Disaster as a Symptom of Environmental Deterioration

It is hard to generalize about the socio-economic details of earthquake damage. It is not hard to draw a parallel with the evidence of environmental change in these habitats, world-wide. And it is important not to ignore the way in which all social and economic development that affects risk is becoming tied into and increasingly shaped by a single international system that produces convergent problems [Hewitt, 1982].

We have identified earthquake disaster especially with mountain regions. There is overwhelming evidence of man-induced change in these habitats. Most is of kinds that increase the impact of earthquake. It does so directly by affecting such things as slope stability. Indirectly, the scope of risk is expanded by the rapid pace of intensified resource use, construction and extension of communications, and of political and military activity into them [UNESCO, 1974] [Eckholm, 1975].

At the same time, the processes of environmental deterioration summed up in "desertification" are most evident in semi-arid, sub-humid and seasonally dry lands, rather than the fully arid lands [U.N., 1977]. Hare [1976] has identified the most serious zones of desertification as having Dryness Indices in the range 2-7, which would embrace the regional climates of a good half of our disasters (Figure 2). Degraded vegetation cover, accelerated erosion, increased run-off and floods are also processes we could expect to adversely affect earthquake risk.

With the earthquake problem, however, we are not dealing in general with either semi-arid areas or mountain areas. Most damage zones involve both. The concentrated areas of earthquake disaster in the world lie at the intersection, as it were, of somewhat dry lowlands or coasts and mountain belts, which in most cases are much wetter. Such is broadly the case for the greatest concentration between the Eastern Mediterranean and Indus Valley (Figure 1). The concentration of disasters in Latin America and California exhibit similar gross relations to habitat. They are less obvious in S.E. Asia where humidity is generally higher. But it is worth noting that, in addition to the prevalence of mountainous terrain, and seasonal climate, the extensive processes of deforestation and other harm to vegetation cover are producing conditions in the landscape there that are analogous in effect to "desertification" [Ranjitsinh, 1979] [Panabooke, 1977].

It is, however, the convergence of the distribution of earthquake disasters upon areas where drier regional climates, and mountain zones meet, that leads us to our next step in their geographical interpretation.

Disaster Sites: Location and Patterns of Damage

It is essential now to move from gross geographical patterns, to the detailed distribution of sites and damage in earthquake disasters. If surface conditions and human activities play any role in seismic risk, it is here that we see it most clearly realized, including the importance of climatic relations.

The first thing to note is that detailed field surveys reveal a more complex and variable picture of earthquake impacts than the idealized image of isoseismal lines whose intensity falls off radially from the epicentral area. The worst damages may be well removed from both the epicenter and reactivated faults. There are commonly multiple centers or patches of damage of given severity. Within a zone that contains damages of the highest intensity, we find structures and people that go unscathed. Not uncommonly there are also isolated patches of the most severe damage in areas far removed from the main damage zones. Rarely is there a spatial coincidence between the different forms of damage used to define earthquake intensity, be it building performance, slope failure, surface rupture, or perceived events. In sum, just as there is a rather poor correlation between earthquake magnitude and scales of disaster [Hewitt, 1978, Table 4], so the geophysical "footprint" itself is only a very gross indicator of the spatial arrangement of damages.

Is it therefore impossible to make any generalizations about damage patterns, in particular as they might point up relations to human and geoecological conditions?

Looking first at an obvious dimension, topography, there is a broadly repetitive type of morphology of damages in most of the disasters. The "typical" event has the main, concentrated pockets of greatest destruction and loss of life in mountain foot or foothill areas, with a "scatter-gun" effect of highly variable damages over a mountainous hinterland. Sometimes as at Skopje in 1963 or Guatemala City in 1976, destruction is largely confined to piedmont or intermontane basin areas. Conversely, in a case like the 1974 Himalayan disaster, the negligible area of mountain foot features made the influence of mountainous topography overwhelming in the destruction of small settlements in crestlines and in narrow defiles. This disaster was, nevertheless, identified with the largest settlement affected, Pattan, which lies on the floor, river terraces and alluvial fans of the Indus Gorge. And as in many other cases, processes initiated at higher altitudes and on very steep slopes wrought the main destruction of life and property at the mountain foot. More commonly, however, we encounter situations intermediate between these two examples. The 1979 Montenegran Coast, the 1976 Friuli, the 1968 Dasht-y-Bayaz or 1964 Niigata disasters were more typical. Most damage was in foothill, piedmont or intermontane basin areas, but with scattered destruction to villages, farms, communications and other installations in surrounding mountain areas.

In itself, the identification of highest damages with piedmont areas is not profound. However, it becomes profoundly important in relation to human settlement, environmental impacts and the climageomorphic relations of earthquake disaster.

The mountain foot environments, the areas where steep slopes give way to gentler ones; where mountain ranges soften into foothills or plunge to the sea coast, were discussed by the ecologist Schimper 1903, p. 702 under the term "Basal Zones". Except locally or incidentally little further work has been done on them.

In terms of seismic risk, the outstanding features of the Basal Zone are those of its heterogeneity, as much as the sharply transitional or "ecotonal" aspect. Seismic shaking is particularly influenced by slope, by the mechanical properties of rock and regolith, by vegetation cover, and moisture conditions. These largely govern the stability of slopes and foundations, and the likelihood of surface rupturing. Variations in them modify the amplitude and form of seismic motion at the surface, or involve very different responses to it. As a landscape, the Basal Zone is characterized almost everywhere by complicated interfingering of erosional and depositional environment. That reflects sharp transitions in the surface geologic or geomorphic processes. The result is a complex mosaic of seismic conditions. The most favorable and least favorable are closely juxtaposed. Steep slopes with little or no superficial deposits pass suddenly onto the thick aprons or fans of colluvial and alluvial sediments. Steep slopes are particularly susceptible to landsliding in earthquakes. Alluvium can mean unstable foundations and, where finer material is in abundance, the problems of soil liquification. Similarly, soil moisture and moisture in rock fissures or the water table greatly affect slope and soil stability.

Basal Zones have complicated patterns of well-drained, modestly drained and poorly drained sites. Spring lines are common. So are areas of coarser deposit or steeper slopes that drain and dry out quickly. The torrential behavior of streams debouching from mountain valleys has a complicating effect, and one that may vary greatly with season and weather conditions. Again, the amplitude of seismic shaking tends to be increased both by steepening slopes and certain types of salient and cliffs; but also in the passage from a solid rock medium to deep alluvium.

It is here that an explanation of much of the complexitiy of damage patterns in the disasters lies. Otherwise identical structures fail at one point and go unscathed or at least much less damaged at a nearby one. Poorly designed structures will survive while nearby, relatively well-designed ones collapse, presumably because of differences in foundation materials or the amplitude of shaking. This was apparent, for instance at Bar and Zelinika in the 1979 Yugoslav disaster. There was massive destruction of modern reinforced concrete port facilities on the coast, while nearby, many seemingly poorer, dressed-stone and masonry buildings survived with often only superficial damage. But the former were on alluvium and fill at the sea's edge, the latter on solid limestone or well-drained regolith back from the coast. Similar situations have been described for many parts of the world. We may just cite reports on the Niigata, 1964; Varto, 1966; Skopje, 1963; and Chile, 1960 earthquakes; [Kawasumi, 1968] [Ambraseys and Zapotek, 1968] [UNESCO, 1963] [Weischet, 1963a and b].

The influence of settlement sites in relation to adjacent mountain slopes or foothills is illustrated again and again in the amount of damage done by landslides at the mountain foot. This is not confined to extreme mountain topography as in Assam (1950), in the avalanche at Yungay, Peru (1970) or the 1974 and 1975 Himalayan disasters and Hindu Kush disaster (1976). In total, destruction by steep slope processes when they reach the mountain foot is probably always much greater. Moreover, the danger of failure of steep slopes is not confined to rock walls. Basal Zones commonly include erosional and tectonic breaks of slope in young sediments. The collapse of poorly consolidated materials where settlements are sited near the crest or at the base of such slopes, has made up much of the damage in some of the worst disasters. Examples include:

Cuzco, Peru	1950
Turud, Iran	1953
Valdivia, Peru	1960
Alaska, U.S.A.	1964
San Salvador	1965
Guatemala City	1976

The geological, topographical and hydrological complexity of the Basal Zone tends to be reflected in vegetation cover, too. Hardly anywhere in the regions we are considering, however, is there much remaining of natural cover. But the transformation of vegetation cover is likely to exaggerate the relative differences in terrain and surface materials as they respond to earthquake shaking. It represents one of the most profound human effects upon these environments.

Human Settlements of Basal Zone Ecotones

Looking again for a moment at the global distribution of earthquake disaster, one simple relation to human populations can be stated: throughout nearly all the areas of concentrated disaster occurrence, mountain fringe settlement is the pre-eminent form. More clearly than anything else it links even the humid areas of S.E. Asia to the rest; their populations being mostly in dense settlements near the coasts of mountainous islands. In the zone of greatest numbers of disasters from the eastern Mediterranean to the Indus Valley, Basal Zone settlement is clearly the case. Here, most of the population is typically distributed in "islands" and more or less continuous ribbons or series of settlements wedged between the mountains and the sea; in the broader intermontane valleys; or between the mountains and arid basins of interior drainage. In the cases of Italy, Greece, Turkey, Iran and Afghanistan this describes the location of not only the bulk of the national populations, but of most towns and cities. In other words, it is not only that earthquake damage is concentrated in the Basal Zone; so is the bulk of human population and wealth at risk [Clarke & Fisher, 1972].

A similar situation applies throughout much of the zones of concentrated disaster incidence in the American cordilleras, and the mountainous islands of S.E. Asia.

It is in this feature of mountain fringe settlement that the significance of climate emerges. In dry or seasonally dry lands mountains are generally favored with higher precipitation and perennial streams or springs. For sedentary agrarian societies or urban development, however, the Basal Zone is where runoff and underground waters can most effectively be taken advantage of--before they are lost to the sea, in coastal marshes and swamps, or the saline plains--and where slope, soil, drainage and climate provide the more congenial conditions for settlement. Often we are looking at an accommodation to environment reflecting prevailing economies and technologies going back some millenia. And if moisture supply is of outstanding importance, other advantages of piedmont locations are significant, too, such as exploitation of the mountain pastures and forests, but also of desert pastoralism, or maritime resources and trade.

In fact, the preconditions for the areas of highest disaster incidence are the result of certain major patterns of what has been called "universal history", patterns as significant in their way as that of the far denser riverine civilizations nearby, where the waters of the mountains cross the dry plains in major streams.

Few of the areas we are discussing are, in fact, without a long history of human change as culture after culture found the gentler, well-watered and wooded slopes of these mountains ideal places for settlement. But in recent years we have seen a new, accelerating wave of changes. It is tempting to attribute much of the recent damage to that.

The details of site and process associated with damages in the earthquakes, repeatedly relate to the particular geoecological and settlement conditions of the piedmont. The major settlements damaged tend to be largely or partly on alluvial fans, or the terraces left by their dissection. Many lap up against or onto the relatively young, contorted, shattered and friable rocks that so often form the outer zone of active mountain ranges. Settlement nuclei may be on outliers and spurs of the foothills, along valleys and bluffs whose existence records the surface outcrop of an active fault. This particular sort of siting that defines the Basal Zone recurs in accounts of damage from Morocco to Baluchistan:

Turud, Iran	1953
Ionian Islands, Greece	1953
Orleansville (El Asnam), Algeria	1954
Agadir, Morocco	1960
Lars, Iran	1960, 1961
Danesfahan, Iran	1962
Barce (Al Marj), Libya	1963
Skopje, Yugoslavia	1963
Varto, Turkey	1966
Trikalla, Greece	1967
Erzincan, Turkey	1967
Dasht-e-Bayaz, Iran	1968
Gediz, Turkey	1970
Bingol, Turkey	1971
Qir, Iran	1972
Lice, Turkey	1975
Friuli, Italy	1976
Bandar Abas, Iran	1977
Tabas-e-Golshan, Iran	1978
Montenegran Coast, Yugoslavia	1979

Most of these events, as noted earlier, also had severe pockets of damage in truly mountainous terrain, where farms and villages, highways and other installations were damaged by the shaking or landslides. But it is the Basal Zone areas that dominate the reports of damage.

However, that is only one perspective on the story, and certainly the pessimistic one. It must be balanced by noting, of course, the great attractions and benefits of these areas and this kind of settlement. And the record of earthquakes is also one of substantial survivals, too. Damage tends to be highly localized in form and extent as we have noted. Specific structures, sitings, land uses and often enough, socio-economic circumstances are involved. But if there are many "unpredictable" or unmeasureable things here, if there is large uncertainty or "chance" in earthquake damage and survival, the literature tends to exaggerate the inevitability of certain damages and the mere good fortune of survivals.

Here, I think, we must beware of using a geophysical "surrogate" for risk. In flood hazard work, for example, it is common to treat the flood plain, and flood height and frequency over it, as an exact analogue of risk. I am skeptical of that approach to floods. But such a simplification is quite unacceptable in earthquake risk. Mapping that strives to reduce damage zone surveys to an epicentral area and isoseismal lines often seems largely artifice.

The essential point turns upon human use of and adaptation to Basal Zone ecotones and, to lesser extent mountainous hinterlands. These are characterized by singularly heterogeneous conditions. But if the complex map of damages indicates the scope of the hazard, what of the equally complex map of survivals, or modest damages?

One could cite the larger municipal area of Kotor in the (1979) Montenegran Coast disaster, or greater Skopje in 1963. While part of these cities was the focus of the worst damages and losses--in the Skopje case almost the only damage--nearby structures and persons suffered little. The total destruction at Skopje was an extraodinary example of concentrated damage to a particularly vulnerable urban neighborhood, sited upon deep, seismically sensitive river alluvium [Poceski, 1969]. Again, the old masonry buildings within the walled city of Kotor were badly damaged. So was a new glass and concrete hotel on the torrential stream delta beside it. But extensive new high rise development, north and south of this, and many smaller homes, survived with little damage. So did most of the old walls.

Obviously, what concerns us most is the plight of victims and vulnerable property. But should we not look much more closely at what survives in disaster zones? May that not record effective, safe siting? well-designed and maintained structures? sensible and informed local behavior? Such investigations seem an integral requirement of social and economic understanding of the sources of earthquake risk. Given the local complexities and enormous geographical and socio-cultural scope of earthquake-prone settlement, the hope of determining general rules about safety in constructions, zoning or emergency measures seems utopian without it. And one might even suspect that, overall, risk reduction is most likely to take place if built upon the existing, successful adjustments of peoples and activities in the disaster-prone areas, rather than upon first principles developed by infant sciences like seismic engineering.

Concluding Remarks

If this exploration has any worth, it must be in the formulation of the problem of earthquake risk. It situates the problem within the complex adaptive and adjustment problems of, especially, people occupying Basal Zone areas. Internally, that involves the safety of sites, or of particular activities at particular sites, in what is a singularly heterogeneous, ecotonal habitat. That must reflect economies that are primarily oriented to the exploitation of this ecotonal setting. They may equally depend upon its locational advantages within surrounding different ecosystems of mountain, lowland or sea.

Seismic risk cannot be expressed in, nor reduced to any <u>one</u> or <u>two</u> variables out of:

i) The location and recurrence of larger magnitude earthquakes.

ii) General seismicity and geotectonic conditions.

iii) "Official" aseismic engineering concepts and codings.

iv) Terrain.

v) Climate.

vi) Population and settlement patterns.

vii) Land use.

viii) Environmental degradation.

ix) Internal man-habitat relations of disaster zones.

x) External relations of high risk areas to the larger space economies of nations and the world.

xi) Wealth, development and relative access to the most "advanced" notions of seismotectonics, engineering, or emergency planning.

xii) Crisis behavior and emergency measures.

The problem lies at the interface of these, and is a complicated "space" variously modeled by them all. That does not prevent it being a characteristic problem of certain distinctive forms of human occupancy of seismic areas.

Since we cannot deal with everything, the strategy my work suggests is essentially an extension and rethinking of the microzoning approach. This is already bringing about important modifications in the sense of seismic risk [USGS, 1979]--although one could see the implications already in, say, the studies following the 1906 California disaster [Carnegie Institute, 1908] But microzoning is still far too much the creature of seismology and engineering geology. Slope, active fault-traces, surface and subsurface materials and other physical factors are important. But their meaning is quite abstract in the absence of a sense of the land uses, social conditions, development pressures, experience and expectation within the communities involved. We can only hope to ground our work here by studying areas with a history of recent, damaging earthquakes. And it is essential to do so by mapping, evaluating and interpreting the socio-economic and ecological background to what survives as well as what is damaged.

This is the objective of my current research examining the sites and surroundings of past disasters in the Eastern Mediterranean and South West Asia. More generally, if this preliminary sketch of the geography of earthquake disaster has any validity it suggests we are dealing with much more than seismic hazard per se. The problem needs to be carefully situated with the complex of conditions involved in the human ecology of settlement, land use and their transformations.

FOOTNOTE

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Appendix A

Dryness Correlates* of 145 Sites of Major Damaging Earthquakes - 1950-1979: By Region and Country

		Date	Location (province, city region)	Dryness Index	Koppen Classification
(1)	Mediterranean (20)				
	Italy	Jan.15, 1968	W. Sicily	1.5 - 2.0+	Csa
		Feb. 7, 1971	Tuscania (Apennines)	1.0	Csa, Csb
		June 15, 1972	Ancona (Adriatic	1.0	Cfb
		May 7, 1976	N.E. Italy (Yugoslav.)	1.0+	Cfb-Cfa
	Jugoslavia				
		July 27, 1963	Skopje	2.0+	Csa
		Oct. 26, 1969	Banja Luka	.75	Csa(Cfb)
		Apr. 15, 1979	Dalmatia, Montenegro	.5 - .7	Csa
	Greece	Aug. 11, 1953	Ionian Islands, western	1.0	Csa
		Apr. 30, 1954	Pindhos Mts. central	2.0	Csa
		Apr. 20, 1955	Thessaly (Volvos)	2.0	Csa
		July 9, 1956	Aegean Islands(Thera)	3.0	Csa
		Mar. 8, 1957	Thessaly (Volvos region)	2.0	Csa
		May 26, 1960	Pindhos Mts. Albanian border - Ioannina	2.0	Cfb, Cfa
		Sept. 1, 1966	S. Peloponnese (Megalapolis)	1.0-2.0	Csa
		June 20, 1978	Thessaloniki	2.0	Csa
	North Africa				
	Algeria	Sept. 9, 1954	Orleansville, Algeria	2.0-3.0	Csa
	Lebanon	Mar. 17, 1956	Beirut, Lebanon	1.5	Csa
	Morocco	Feb. 29, 1960	Agadir, Morocco	5.0	BSh
	Libya	Feb. 21, 1963	Barce, Libya	4.0-7.0	BWL
	Israel	Mar. 31, 1969	Israel, Sinai Peninsula	2.0+	Csa
(2)	Southwest Asia (42)				
	Turkey	Aug. 13, 1951	(N) Cankiri, Changra	2.0	Csa
		Jan. 3, 1952	(E) Erzurum (Hasankale)	2.0	Cfb, Dfc
		Mar. 18, 1953	(NW) Istanbul (Canakkale)	1.5	Csa
	May 26,	May 26, 1957	(N-C) Bolurov.	1.5	Csa
		Aug. 19, 1966	(E) Varto prov.	1.5	Dfc. Cfb

* Note: I am indebted to Professor Dieter Henning of Bonn for the maps of the Dryness Index from which our values are derived and to Ms Katherine Miller, graduate student at Wilfrid Laurier University who did the detailed preparation of this table.

(Turkey)	July 22, 1967	(NW Anatolia) Adapazari	1.5	Csa
	July 26, 1967	Erzincan and Tunceli provs.	2.0	Cfb
	Mar. 28, 1969	(W) Alasehir	1.0	Csa
	Mar. 28, 1970	(W) Kutahya prov. (Gediz)	1.5	Csa
	May 12, 1971	(S.W) Burdur-Tauras Mts.	1.5	Csa
	May 22, 1971	(E) Bingol prov.	2.0	Cfb
	Sept. 6, 1975	(E) Lice	< 1.0 - 2.0	Dfb - BSk
	Nov. 24, 1976	(E) Van prov.	1.5 - 2.0	Dfb - BSk
Iran	Feb. 12, 1953	Turud, Elburz Mts.	10.0	BSk
	Oct. 31, 1956	(S.W) Bostak, Lanstan	7.0	BSh
	July 2, 1957	(N) Caspian Coast	2.0	Csb, Dfb
	Dec. 13, 1957	(W) Central Zagras Mts.	1.0 - 5.0	Csb, BSh
	Aug. 16, 1958	Kermanshah, Zagros Mts.	5.0	Csb, BSh
	Apr. 25, 1960	(S) Laristan, Lar	7.0	BSh
	June 11, 1961	(S) Lar (Deh Kuyeh)	7.0	BSh
	Sept. 1, 1962	(N.W) Danesfanan	5.0 - 7.0	Csb (Dfb)
	May 1, 1968	(W) near Turkish border	2.0 - 3.0	Dfb, Dfc
	Aug. 31, 1968	(N.E) Khurasan prov.	2.0 - 3.0	BSk (Csb)
	Jan. 3, 1969	U.S.S.R. border, Khurasan	3.0 - 4.0	BSk (Csb)
	July 30, 1970	(N.E) Khurasan prov.	4.0 - 10.0	BSh (Csb)
	Apr. 10, 1972	(S) Fars prov. (Ghir)	5.0 - 7.0	BSh (Csb)
	Mar. 21, 1977	(S) Bandar Abbas	7.0 - 10.0	BSh
	Apr. 6, 1977	(C and S.W) Shakr Kord	2.0 - 3.0	BSh (Csb)
	Dec. 20, 1977	Kerman prov. (Zarand)	5.0	BSh (BWh)
	Sept. 16, 1978	(E) Tabas (Khorasan)	10.0	BWk
	Jan. 17, 1979	(E) Qaen (Khurasan)	4.0	BSk (Csb)
	Nov. 14, 1979	(N.E) Qaen, Bohnabad	5.0	BSk
Afghanistan				
	June 8, 1956	Kabul	5.0	BSk
Pakistan				
	Dec. 28, 1974	Pattan (Karakoram)	< 1.0 - 3.0	Csb
India	Aug. 16, 1950	Assam prov/Burma	.5	Cw
	July 21, 1956	Bombay to Pakistan border	3.0	BSh
	Sept. 2, 1963	Kashmir, W. Himalaya	2.0 - 3.0	Cw (H)
	Dec. 11, 1967	Western Coast (Koyna)	1.0	Am
	Sept 2, 1972	N.W Kashmir - Karakoram	.5 - 2.0	BWk
	Jan. 19, 1975	Kashmir - Tibet border	3.0	BSk
Nepal	June 29, 1966	Western Nepal (Bajhang)	.5 - 1.0	Cw (H)
S. U.S.S.R.				
	Apr. 25 - July 19 1966	Tashkent (n. Uzbekistan)	4.0	BSk

(3) South and Central America (32)

Mexico	July 28, 1957	Guerrero state (Mex. City)	2.0	Cw - BSk
	July 4, 1964	Guerrero	2.0	Cw - BSk
	Sept. 25, 1968	Chiapas state (Guat. border)	1.0 - 1.5	Aw, Cwb
	Jan. 30, 1973	Colina, Jalisco states	1.5	Cw - Aw
	Aug. 28, 1973	Puebla, Veracruz and Oaxaca states	1.0 - 2.0+	Cw, Aw
Guatemala				
	Feb. 4, 1976	Guatemala City	1.5+	Cwb, Cfb
El Salvador				
	May 6, 1951	(SE) Tucuapa, Chinameca	.75 - 1.0	Aw
	May 3, 1965	San Salvador and environs	1.0	Aw, Cwb
Nicaragua				
	Aug. 3, 1951	Potosi (NW)	1.5	Aw
	Dec. 24, 1972	Managua	1.5+	Aw, Cwb
Venezuela				
	Aug. 4, 1950	Lara state (Tocuyo)	1.0	BWh
	July 30, 1967	Caracas (wide area)	2.0	BWh
Colombia				
	July 10, 1950	(NW) Bogota, Santander	.75	Cw
	May 24, 1957	Buenaventura	.5	Cw
	July 30, 1962	W. Colombia	.5	Af
	Feb. 9, 1967	Huila Dept (Guacamaya)	1.0	Cw
	Nov. 24, 1979	(N) Pereira	.5	Aw (Af, Cw)
	Dec. 13, 1979	(W) Tumaco, coast	.5	Af (Aw)
Ecuador	Apr. 9, 1976	(N) Esmeraldas (mtns)	.5 - 1.5	Af, Aw
Peru	May 22, 1950	Cuzco	3.0	Cw
	Jan. 19, 1958	Arequipa	7.0	BWh
	Jan. 14, 1960	Arequipa	7.0	BWh
	Oct. 17, 1966	Caltao, coast	50.0	BWh
	Oct. 1, 1969	Lampa, Chilifruta	20.0	Cw
	May 31, 1970	Yungay, Caras	3.0	Cw, BWh
	Dec. 9, 1970	Peru/Ecuador border	2.0 - 3.0	Cw
	Apr. 25, 1974	Arequipa	7.0	BWh
	Oct. 3, 1974	Lima, Canete	50.0	BWh
Argentina				
	Nov. 23, 1977	San Juan prov.	7.0 - 10.0	BSh (ET)
Chile	May 21, 1960	Concepcion Valdivia	.5 - 1.0	Csb
	Mar. 28, 1965	Central Chile (Valparaiso)	3.0	Csb
	July 8, 1971	near Valparaiso Santiago	3.0 - 4.0	Csb, BWh

(4) E. and Southeast Asia (28)

Mongolia	Dec. 4, 1957	E. Altai Mts.	5.0 -> 10	BWk
Japan	Mar. 4, 1952	Hokkaido, N.E. Honshu	.75 - 1.0	Dfb
	June 16, 1964	(N) Niigata, Akita	.5	Cfa
	May 16, 1968	N. Honshu (Tokachi-Oki)	.5 - 1.0	Dfb (Cfa)
	June 17, 1973	Hokkaido	.75 - 1.0+	Dfb
China	Dec. 21, 1951	Yunnan prov	n.a.	Cwb
	July 25, 1969	Swatow area	1.0	Dwb, BSk
	May 11 , 1974	Szechwan-Yunnan	n.a.	Cwb, Cwa
	July 28, 1976	Tangshan	1.5	Cfa
	July 9, 1979	Chiangsu prov. (Shanghai)	1.5	Cfa
Taiwan	Oct. 22, 1951	Hualien, Taitung	.75	Cwa
	Nov. 25, 1951	Hualien (e. coast)	.75	Cwa
	Jan. 18, 1964	(S) Paiho, Tungshan	.75	Cwa
Philippines				
	Mar. 31, 1955	Mindanao	.5 - 1.5	Am
	Aug. 1, 1968	Luzon (Manila)	< 1.0	Am
	Aug. 16, 1976	Mindanao	.5 - 1.5	Am
Indonesia				
	Oct. 20, 1958	Java (Blitar)	< 1.0	Aw
	Mar. 15, 1965	Sanana Is. Ceram sea	< 1.0	Am
	Feb. 20, 1967	Java (Malang)	< 1.0	Aw
	Aug. 14, 1968	Celebes, Tuguan Is	1.0 +	Am
	Feb. 24, 1969	Celebes (Madjene)	< 1.0	Am
	Jan. 9, 1976	huge area	n.a.	Af
	June 26, 1976	West Irian Jaya	n.a.	Af
	July 14, 1976	Bali (Seririt)	< 1.0	Am
	Oct. 29, 1976	Irian Jaya	n.a.	Af
	Aug. 19, 1977	S. of Sumbawa Is.	< 1.0	Am
New Guinea				
	Jan. 18, 1951	Papua (Mt. Lamington)	n.a.	Af
	Oct. 31, 1970	Port Moresby, Madang	< 1.0	Aw

(5) Africa (3)

Uganda	Mar. 20, 1966	Ruwenzori foothills	1.0+	Aw
Zaire	May 18, 1966	north Kivu prov.	1.0+	Aw
South Africa				
	Sept. 29, 1969	Cape, Natal prov.	1.5 - 2.0	BSh, BWh

(6) Non-Medit. Europe (1)

Romania	Mar. 4, 1977	Bucharest	1.0	Cfb, Cfa

(7) North America (15)

California U.S.A.				
	Aug. 15, 1951	Long Beach	n.a.	Csb
	July 21, 1952	Kern County	n.a.	CSa
	Aug. 22, 1952	Bakersfield	n.a.	CSa
	Dec. 21, 1954	Eureka	.5	H/BWk
	Jan. 25, 1955	Long Beach	4.0	CSa, CSb
	Oct. 25, 1955	San Francisco	1.5	CSa, CSb
	Mar. 23, 1957	San Francisco	1.5	CSa, CSb
	Apr, 4, 1961	Los Angeles	3.0	CSa, CSb
	Oct. 2, 1969	Santa Rosa	.75	CSa, CSb
	Feb. 9, 1971	San Fernando	3.0	CSa, CSb
	Feb. 21, 1973	Oxnard	2.0	CSa, CSb
	Aug. 17, 1978	Santa Barbara	2.0	CSa
Montana	Aug. 17, 1959	Hebgen Lake	n.a.	BSk
Alaska	Mar. 28, 1964	Anchorage	.5	Dfc
Washington				
	Apr. 30, 1965	Seattle, Tacoma	.5	Cfb

(8) Australia, Oceania (4)

New Zealand				
	May 23, 1968	South Island	n.a.	Cfa
Australia				
	Oct. 14, 1968	(SW) Perth	n.a.	Csa
Hawaii				
	Apr. 26, 1973	Hawaii Is.	n.a.	Af
	Nov. 29, 1975	Kilauea Rift	n.a.	Af

Total - 145