Sources of Liability for Geologic Hazards

The range of liability for damage from geologic hazards has a basis in common law and consequently is explicit in most states as such or as modified by statute.

The range of liability extends from absolute through phases of contingent to limited or no liability. In general, absolute liability in civil cases is imposed for acts which are ultrahazardous, inherently dangerous, or public nuisances. Contingent liability exists where an act or omission is intentional or the result of a breach of a duty which leads to a foreseeable damage. Liability is limited or there is no liability where the damage resulted from an act of God, where there were supervening acts of others or where no legal injury occurred. For each potential attachment of liability, there is a defense or range of defenses. In addition, persons who speak out in a defamatory manner may incur liability for that speech unless protected by privilege or on constitutional grounds.

The legal basis for liability for damage from geologic hazards is in tort and property law (including water law) where traditionally the different degrees of liability have been imposed for differing damages to land and the use of land. Loss of vertical support, flooding, and pollution are commonly absolute liability or intentional torts. Damage from landslides and mixed geologic situations commonly fall under the rules of negligence and one would expect the same to apply to damage to man-made structures from earth movements. Interferences with groundwater supplies may result in civil liability depending on one of the four major theories of groundwater law.

Professional geologists in public practice or those who involve themselves in public debate without adequate preparation are likely target defendants where damages result from projects which incorporate their recommendations, where they fail to act when there was a duty to do so, and where their unwarranted alarms cause expensive delays.

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Exploitation of Very Low-Grade Uranium Deposits

Where once there was great optimism about the economic exploitation of very low-grade uranium deposits (0.002 to 0.010% U_3O_8) such as occur in the Chattanooga Shale and the Conway Granite, there now is almost equivalent pessimism. A 1978 National Research Council report "rules out" shales and granites as future uranium sources, because of the "enormous" mining and processing costs required and because the environmental impacts of the "many huge operations" that would be needed are not likely to be acceptable. Such a conclusion appears premature. Gold is won at an after-tax profit from deep-mined refractory ores in which it is found in concentrations as low as 3 ppm (0.0003%), much lower than the low end of the range cited for uranium in shales and granites; the price-grade relations for gold suggest that 0.006% U_3O_8 rock could become ore at a price well below $150/lb. The energy balance appears positive even for once-through LWR burning; with breeders, it would be strongly positive. To meet the projected 1980 United States annual requirement of 19,000 short tons of U_3O_8 from a single mine in rock containing 0.006% U_3O_8 at 70% recovery would require moving a minimum of 1.24 million short tons of rock a day—a large amount, but easily within the ability of present technology (5 or 6 large copper pits would be the equivalent), and possibly not unacceptable in a time of energy scarcity. The major constraint on potential uranium supply remains political, rather than geological or technological.

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Generation of Debris Flows and Turbidity-Current Flows from Submarine Slides

Relatively few data have been published that demonstrate that sediment gravity flows can be generated from slides and slumps. Such evidence can be found in a north-trending, seaward-prograding, continental-slope sequence which existed in central Nevada during the early Paleozoic. Translational slides on this slope are up to 400 m wide and 10 m thick. These slides moved semi-lithified, black, thin-bedded, hemipelagic limestone. Once the slide was in motion its transformation into mass flows began at its base and thin margins. Probably the rupture strength of these parts of the slide was exceeded and movement by plastico-viscous flow resulted because of a variety of factors which includes strain, mechanical shock, and incorporation of water. The development of clasts in the basal shear zone and thin margins of the slides resulted from overfolds and nearly horizontal beds within the slides which gradually separated into thin tabular fragments. Clast development progressed as the slide continued to move downslope until the base and margins of the slide attained a completely conglomeratic texture. The clasts at this stage assumed a random or subparallel orientation supported by a carbonate mudstone matrix.

Conglomeratic debris-flow deposits generated by these slides occur in channels up to 400 m wide and 12 m thick. Field data suggest that a downslope transition occurs from debris flow to turbidity-current flow. Many of the conglomeratic turbidity-current flows on the lower slope probably originated as debris flows which in turn were generated from slides higher on the slope. These turbidity-flow deposits occur in channels up to 100 m wide and 2 m thick and contain clasts identical to those in the debris-flow deposits.

A further genetic link may exist between these slides and the slide-generated mass-flow deposits. The mechanics of flow and the resulting fabric and sedimentary structures in the mass-flow deposits were influenced by the nature of the clasts generated by the slides. Preliminary data suggest that the size, shape, and original orientation of the slide-derived clasts were strongly controlled by the bedding characteristics, degree of induration, and style of deformation of the slides.

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Surface Seismic Methods Applied to Coal-Mining Problems

Several tests have been conducted to determine the feasibility of using surface seismic methods to solve coal-mining problems. In particular, we have attempted to detect coal-seam discontinuities caused by erosional sand channels and to locate abandoned workings. An inexpensive test program to evaluate the probability of success at a given mine site was developed and has proven effective. Seismic data were acquired at four locations and features associated with coal-seam discontinuities were identified on the seismic sections. The data were used to predict the location, and in some cases, the nature of the coal-seam discontinuity. Core and geophysical log data were used to provide subsurface control and to test the validity of the seismic interpretation.

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Thick Sediment Accumulations Beneath Continental Margin of Outer Bering Sea

Multichannel and single-channel seismic reflection profiles across the outer edge of the Bering Sea Shelf between Cape Navarin and the Aleutian Islands reveal thick sedimentary sections underlying the continental slope and rise. This segment of the Bering Sea margin, about 700 km long, is covered by 200 to 3,400 m of water and is incised by several large submarine canyons. The sedimentary section overlying acoustic basement ranges from 0 to 10 km in thickness, and the thickest parts (7 to 10 km) are located at the base of the slope along the northern and southern areas of the margin. A maximum thickness of 10 km (5.9 sec, two-way) occurs in uplifted rise deposits that lie in 800 m of water near the mouth of Zemchug Canyon.

Recent dredging along the continental slope indicates that upper Eocene or lower Oligocene sediment lies unconformably on an Upper Jurassic acoustic basement. The reflection profiles across the sediment-draped areas of the margin suggest that only the upper half of the thick sedimentary section at the base of the slope is younger than early Oligocene. The age of the deeper sediment may be as old as Mesozoic.

Several aspects of the sediment wedges along the Bering Sea margin make these wedges favorable targets for future hydrocarbon exploration: (1) the large total thickness of Cenozoic sediment; (2) the presence of internal structural and stratigraphic features such as diapirs, faults, crustal warps, onlaps, and pinchouts; and (3) the likelihood of Cenozoic source areas rich in organic and coarse-gained detrital debris.

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Crude Oil-Like Hydrocarbons in Recent Sediments of Santa Barbara Basin

Significant amounts of indigenous hydrocarbons have been found in recent sediment cores from the Santa Barbara basin offshore of southern California. The molecular composition of these hydrocarbons is like that of crude oil and appears to be uniform across the basin and not altered by depth of burial. The molecular composition of this incipient crude oil differs from local crude oils and oil seeps and from hydrocarbons contained in underlying, geologically older rocks. Phytoplankton, which are so abundant in the nutrient-rich waters of the Santa Barbara Channel, appear to be the major source of the hydrocarbons. Study of these cores seems to be leading to the general conclusion that the process of oil generation starts very early in the depositional cycle.

One piston core from the basin contained a 2-m thick sand and shell layer buried 2 m below the mud line. In contrast to the surrounding clay muds, a large fraction of the extractable organic matter from the sand-shell layer was hydrocarbons, and the hydrocarbons exhibited a more crude oil-like composition than the hydrocarbons in the clay. Thus, it appears that hydrocarbons have migrated from organic-rich, clay muds into a reservoir bed within a few thousand years.

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Antarctica and Gondwanaland

From field studies during the last 80 years, the geology of Antarctica is sufficiently known to allow definition of two main provinces—East Antarctica (mainly east longitudes) and West Antarctica. East Antarctica is a continental landmass with an ancient basement complex overlain by a subhorizontal sedimentary and volcanic sequence. The basement rocks (Archean to early Paleozoic) include a variety of igneous and metamorphic types; granulitic rocks such as enderbite and charnockite are widespread. The overlying stratified sequence (Devonian to Jurassic) of mainly clastic sedimentary rocks contains coal, the *Glossopteris* flora, and mafic sills and flows. West Antarctica is a diverse and complicated terrane of Phanerozoic rocks. Fossiliferous Cambrian beds are present in one range, but no definitely Precambrian rocks are known, although some could be that old. Five tectonic zones have been identified in Antarctica—the ancient shield and four Phanerozoic orogenes.

To understand the history and resource potential of Antarctica, it must be considered as a central piece of Gondwanaland with ties to all the other major fragments. The supercontinent had obtained most of its area by late Precambrian time, and the Pacific border was an active continental margin from then until early Mesozoic time. Major orogenes are traceable into the other Gondwanaland fragments and provide important ties for reconstruction. Breakup began during the Jurassic with separation of South America and Antarctica from Africa, and continued into the Cretaceous with the separation of New Zealand, and probably India, from Antarctica. The parting of Australia and Antarctica occurred during Eocene time. Breaking of the last linkage with South America during middle Tertiary time led to formation of the Antarctic Circumpolar Current and the modern isolation of Antarctica.