The Engineering Geologist

THE GEOLOGICAL SOCIETY OF AMERICA

NEWSLETTER OF THE ENGINEERING GEOLOGY DIVISION OF THE GEOLOGICAL SOCIETY OF AMERICA

Volume 15, Number 4 October 1980

Thoughts on Environmental Geology

L. Calembert, Professor at Liège University (Belgium)

Chairman Allen W. Hatheway's message (Newsletter E.G.D., vol. 15, no. 2) stresses the importance of *environmental geology* and the increasing role which *engineering geology* could and should play in this area. In this connection, I feel it is interesting to submit some ideas inspired by our studies in Belgium; that is in a country which, in many ways, represents a test-region in spite of (or perhaps because) the absence of earthquakes, volcanic eruptions and tidal waves.

Belgium has a big population (10,000,000) for a small area (30,500 km²) and is characterized by the density of its buildings, industries, open and underground mines (old and new) and infrastructure. Some people refer to it as an enormous freeway system linking urban centres which are on the point of coalescing. On the other hand, the sub-soil (one of the most carefully studied in the world) offers an extremely varied geological structure and a very inequitable distribution of resources, including water. These circumstances have produced practicing *geological engineers* who are open to the natural sciences and engineering at the same time.

With the acceleration of technical civilization and the gravity of certain of its consequences, *engineering geology*[1] has quickly established itself. It applies the principles and the methods of mineral and related sciences to the work of the engineer for whom the characteristics of the soils, the rocks, the rock-masses and subterranean waters are as important as the possible role of current or potential geological processes. It joins together the observations of the naturalist and the techniques of the engineer as far as the conception, execution, efficiency, security and the economy of structures; the exploitation and the conservation of the mineral and water resources; protection against natural risks but also those caused by human activity. Tributary of natural conditions and of the nature of the project, many different disciplines are called for: mineralogy, petrography, sedimentology, stratigraphy, tectonics, palaeontology, geomorphology, photogeology, hydrology, hydrogeology, geophysics, geochemistry, soil and rock mechanics, hydraulics—not counting the services of the computer. Stimulated by its pluridisciplinary nature, and by ever improving means of exploration, engineering geology has fulfilled for 30 years already a multiplicity of tasks in conditions which are often difficult: the poor quality of available land, work on imposed sites, ever-increasing size of jobs; interference between infrastructure, usage of mineral resources such as water and public services; the necessity of long-term planning.

Urban geology[2] brings the applications of engineering geology to the urban environment where natural and human factors work closely together, demography brings an explosive increase in built-up areas with many consequences, inevitably underground urbanisation is developed, and socio-economic constraints weigh very heavily.

Finally, spilling over the urban areas as man extends his grasp on the geological environment and as geological phenomena in the widest sense—influenced or not by man—more and more affect the living conditions of the population, engineering geology flows into *environmental geology*[3]. The latter has at present an autonomy which relates to the specific nature of its objectives and several constraints of its own. I shall now address these particularities.

Environmental geology represents that part of ecology which relates human relationships (and more generally life) to mineral substances, subterranean water, geological processes. The preoccupations implied for engineers safeguarding the environment also introduce new dimensions into engineering geologic studies:

- to obtain results as quantitative as possible which can be integrated into the pluridisciplinary study of systems which are at once natural, complex and interdependent.
- to anticipate and eliminate short and long-term damages due to the intervention of natural or anthropic factors and to their interaction beyond the immediate application carrying out within the prescribed rules.
- to collaborate with engineers of different specialisations, architects, urbanists, planners, promoters, sociologists, economists, lawyers, administrators, politicians (who use validly their power of decision within the limits of good

[1] L. Calembert, 1980, Géologie de l'ingénieur, Encyclopaedia Universalis, Suppléments, p. 662–664, Paris, 1980.

[2] L. Calembert, 1974, La géologie urbaine dans le monde d'aujourd'hui, Bull. Séances Acad. Royal des Sc. d'Outre-Mer, fasc. 2, p. 310–327, Bruxelles.

[3] L. Calembert, 1976, Raisons de'être de la géologie de l'environnement en Belgique, Recherche et Technique au Service de l'Environnement, éd. Cébedoc, p. 69–107, 28 fig., Liège.

information!) and to participate thanks to an excellent mutual understanding in the collection and checking of the results, in their interpretation and presentation to the different parties.

• to intervene in informing public opinion because of its role in democracy and because environmental protection must interest the man in the street, influence his daily behaviour, change his attitude, make him conscious of the notion of the collective responsibility and the socio-economic importance of the problems and management of the environment.

In order to demonstrate the importance of the principal objects of our studies in environmental geology, I will examine respectively the materials, natural and anthropic factors, problems relating to water and to major works, questions of local planning and specialised education.

Natural and artificial materials: embankments, loose soils and unconsolidated rocks, solid rocks and rock masses are all different because of their nature, texture, structure and thus possess different hydrogeological and geotechnical properties which affect their behavior and qualities depending on the environment.

Embankments of silt, clay, shales, burned shales (burning of coalmines spoil-heaps), wastes of ore-dressing (and others), cover depressions, fluvial channels, old brick fields, slopes, shored-up structures. They cause differential settling, subsidences, land-slips and underground water pollution.

Some *unconsolidated soils and rocks* when saturated undergo plastic deformation and flow, hindering earthworks and affecting the stability of buildings. A common result is fracture of pipes (sewers, waterpipes, gas conduits, and so on).

According to the petrography and the structure at the scale of the sample and of the rock mass themselves, *solid rocks* can react differently to the physical and chemical actions of underground water and to the strains, its value as a constructive material can be compared with its attributes as an aquifer. The majority of disasters are not due to ignorance of site conditions (structural discontinuities, degree of alteration, and so on) and of the effects created by the projected work: raising or lowering of the water table, chemical reactions with the underground waters, and so on.

Laboratory and in-situ tests and geophysical methods such as seismic ones allow the identification of the properties of materials and rock masses in so far as samples and borings are representative and the interpretation of results correct, which depends on engineering geology.

Natural and anthropic factors often act in concert on the environment.

Mass movements, rapid or slow, but which can in the most part be suddenly accelerated by unexpected factors either natural or human, range from creep and solifluxion through mudflows, rockfalls and landslips to avalanches. Their variety relates to the properties of the materials, to the presence of water, steam or air within the moving mass, to the slope of the stable bedrock, to the kind of impetus imparted to the unstable mass: exceptional and prolonged rainfall, thaw, microseismic shock, movement of the water table, and so on. The size of the damage depends on the volume and the nature of the displaced materials, on the speed of the movement, on the topography of the affected site and on the density of constructions.

Silts, loess, weathered mantle, and colluvium all are prone to mass movement: atmospheric or local conditions (vibrations, breakage of drain pipes, overloading of the upper slopes or excavations of the lower slopes) only help to start the movement. Deposits of waste, ash, slags, or spoil-heaps require a special engineering geology study: paleotopography, subsoil, surficial and underground waters (flood and drainage control) and forecast of peripheral uplift and subsidence in connection with the pressure of the embankment and the mobility of the substratum.

Subsidence resulting from settlement or underground excavations either natural (karst phenomena; drying of silts, of clays, of peat; percolation of water into loose structure deposits which later become compacted) or as a result of human activity (underground mining, pumping, water catchment). The preponderantly vertical movements bring about sinking, slumping and collapse, water accumulation and infiltration, aquifer pollution, and so on.

Faults can be activated by deformations of the Earth's crust, earthworks, and the influences of mining. Even if they are passive they represent drains if they are pervious, screens if they are impervious, and in both cases they modify the behaviour of subterranean water. Crushed rock can be more easily weathered and the percolating water can affect the walls.

Numerous *anthropic factors* cause, accelerate, aggravate geological and related phenomena: old underground works (for coal, calcium, phosphate, alum shales, marls, flints, brick-earths, sandstones); irreversible degradation of the mechanical and hydrogeological properties of rocks in mining areas; blasting in quarries, and so on. It is noticeable that the building of a highway, of an aerodrome, the installing of a sewage treatment plant, and so forth, spoils the environment either because the work being badly conceived in relation to the site deteriorates and causes damage; or because the execution of the project brings with it geological changes which threaten its security; or finally because the different activities undertaken introduce pollution or other harmful effects. In most cases, the severity of the damage is caused by ignorance of the real geological and hydrogeological conditions of the site which the work directly or indirectly affects.

Water-related problems are numerous and widespread: many have already been mentioned. Water stagnant or circulating in the soil and the subsoil physically and chemically modifies minerals and their mechanical properties. The nature of underground waters and their natural or acquired variations affect domestic and industrial uses, its attacks on concrete and pipes, and so on. Hydrogeological conditions determine whether certain fluids can be stored underground or if used or refuse waters can be injected into the subsurface, whether a site is suitable for a sewage treatment plant or a toxic waste landfill.

Our attention has been drawn to two important cases: the frequent occurrence of buried parts of fluvial channels covered over by slip and solifluxion; the effects of building and more generally of land rendered impervious to surface water and of the reduced recharge of the aquifers.

Aquifers of different kinds deserve a close study. Phreatic water in the weathered mantle and loose surficial rocks is usually distributed sporadically, the supply and the reserves fluctuate, the water table aquifer is irregular and often without a filter cover and thereby threatened by nearby sources of pollution. Alluvial aquifers (in alluvial plains, stream terraces, alluvial cones) are subjected to repeated fluctuations, natural or unnatural (pumping, foundations forming flow obstructions, infiltrations beneath embankments) in heterogeneous materials, of varied composition and granulometry, frequently sensitive to water. In particular, geological structures (fossil channels and swamps, alluvial islands, and so on) are often characterised by rapid lateral facies and thickness variations and cause differential settling, fine particules transport, rearranging of elements, local subsidence as well as fluctuations in the water level which affect foundations. Aquifers in joints and cracks deserve special attention because of their behaviour which cannot be understood without the definition of the structural phenomena: that is, greater enlargement of the area of depression, and a resulting loss of the hydrological and ecological balance in the region.

The definition of parameters and devices of protection for springs and other potable water sources, mineral and thermomineral water-catchments; precautionary measures to avoid the intrusion of dirty or saline water into aquifers must necessarily rely on in-depth studies which take into account existing and future human activities in a given zone.

Karst phenomena are widespread in the Devonian and Carboniferous limestones and in the Cretaceous: actual, recent or fossil cavities, surficial or underground, active or passive, subjected to the action of vadose or phreatic water. The cavities are empty, or partially or wholly filled with different materials. They evolve in a complex fashion: dissolution, especially subfluvial, emptying by vadose water or draining off from below, renewal of dissolution as the water level sinks, enlargement *per ascensum* and collapse of the roof. Soluble sites present significant environmental difficulties: areas of weak or unstable subsoil, heterogeneous bodies in respect of settlement coefficient and other parameters, corrosion and pollution by the removal of rain and used water, water inrush into underground works.

Extensive pumping in karst regions either owing to public works or to urban water supplies cause disastrous breakdowns at the surface and enormous damages to houses, cement works, electrical power stations, road systems, and so on. The geological make-up of the subsoil (peat in alluvium, Tertiary sands, chalk with paleokarst which can be reactivated, and so on) as well, of course, the kind of foundation play a major part.

Major engineering works depending on their nature, size and site encounter certain of the difficulties described above, and I will not dwell on them. But I do have to stress one point. Because of their large size and their public interest, major works (road systems, tunnels, subways, industrial parks, pumped storage plants, nuclear power stations, and so on) require complete preliminary investigations in engineering geology (in-depth definition of lithological, structural, hydrogeological characteristics, examination of excavation and support methods; determination of mechanical properties of materials and rock masses; geophysical and seismotectonic evaluations, and so on). Ways have to be found to relate the results thus obtained to environmental geology, the purpose of which is to use these techniques in advance to protect the environment within the whole region and for all activities for which its application is legitimate.

Regional planning can only be successful if an exhaustive inventory is taken of all relevant natural phenomena, especially geological and hydrogeological ones. Ideally, the results of most of the studies discussed above should be used in the compilation of the master plans.

As an example, mineral exploitations (such as raw materials, energy resources, arable soils) create problems which are too often neglected, in consideration for the environment unless socio-economic interests are to be sacrificed. Some resources of low intrinsic value (water, clay, loess, sand, gravel, stone, crushed stone; raw materials for cement, concrete, manufactured materials, and so on) only occur in limited quantities, can only be extracted in their very site and then only if the economic conditions of market and transport allow it. Other resources of greater intrinsic value occur in deposits which, if they were to be exploited, would disturb the environment. In many cases, the solution is to study the simultaneous or successive use of the area to many ends, then restore the environment, which requires here too the exact recognition of the local and regional geological and hydrogeological characteristics. The previous inventory of useful materials and how they must be exploited, of the protective measures for surface and underground water and of restoration treatments which must *precede* all urbanisation and industrialisation projects.

The experience obtained during the studies pointed out here and the growing interest which public opinion and managers of private and public organizations now show for the safe-keeping of the environment has incited the creation, at Liège University, of a special *complementary* course for *civil environmental engineers* which is open to engineers of all disciplines. It is possible to take an examination after one year's study at least but students (many of whom already have a profession) are allowed to spread the examination over three years. According to their previous education and/or their future objectives, these engineers can choose one of several options. In the option "Natural and human environment" appear questions in *Environmental geology and hydrogeology* and within the framework "Applied sciences," appear the *Special questions in environmental geology and hydrogeology*.

To sum up, we believe that the time has passed when lost raw materials, neglected or polluted water, damage to people or to properties, due to ignorance of the geological, hydrogeological and anthropic factors, were the objects only of regrets, repentances and wise *post mortem* observations.

The principal causes of the recognised errors and disasters can be summed up as follows:

- incomplete or incorrect definition of the geological hydrogeological conditions of a site or a region
- the lack of adaption of the project to the real conditions of the natural framework
- the lack of insight into the interaction between geological and anthropic factors.

An *adequate study* has to include *environmental geology* whose job it is also to list and interpret the facts, to learn the lesson from them and to liberally diffuse the results of the interdisciplinary studies to the benefit of the community (data banks, geotechnical maps, maps showing zones prone to predictable risks, and so on).

At a time when cooperation with underdeveloped countries becomes an obligation, environmental geology represents a privileged tool for the transfer of knowledge and technology[4].

[4] L. Calembert, 1975, Activités d'un laboratoire de géologie appliquée dans les pays en développement, Bulletin des Séances de l'Académie Royale des Sciences d'Outre-Mer, no. 3, p. 416–427, Bruxelles.

CHAIRMAN'S MESSAGE

Geology of total urban development—Report of a visit to the Republic of Singapore

Allen W. Hatheway, Cambridge, Massachusetts

For the month of May 1980, I had the good fortune to undertake fieldwork in the Republic of Singapore (Fig. 1). This field work involved mapping, boring log review, and borrow material location for a major water supply project. Needless to say, I took great advantage of the visit and went about learning as much as possible of the geology of the island republic. The result of this cram course in urban geology of the tropics has been very much an eye-opener to me (Fig. 2). Allow me to impart some of my findings and discoveries to you! I hope to follow this initial report with an expanded treatment of Singapore for the *Cities of the World* series that has been initiated in the *Bulletin* of the Association of Engineering Geologists.

There is very little of tradition in Singapore; it is a new nation of only 15 years and its predecessor colony was founded only 161 years ago. Known as *Singapura* in the Malay language, or "Lion City," the present city-state is thought to occupy the site of an ancient Sumatran colony founded in the 13th or 14th centuries and subsequently destroyed by Javan raiders about 1360–1365 (U.S. Army, 1977). Afterward, its small but excellent natural harbor and broad tidal Singapore River became a pirate haven until Sir Stamford Raffles, the British envoy of the East India Company, found it by reference to an earlier manuscript. This was in 1819 and Singapore then consisted of a population of some 120 Malays and about 30 Chinese. Arranging a political settlement of convenience, Raffles saw to the acquisition of the 603 km^2 island from its then-ruling Malay *Temenggong*. Raffles developed a thriving regional trading port within five years. Singapore eventually became a Crown Colony and remained such until its achievement of internal self government in 1959. In 1963, Singapore became a semi-autonomous state of Malaysia and finally parted amicably with that federation on 9 August 1965.

What is so tremendously exciting about Singapore is the energy of its people, the dynamics of its economy, and the juggernaut-like nature of its urban development. Although Singapore the colony had been prosperous, it was an overcrowded and unhealthy place at the advent of WWII. Japanese forces crossed the Straits of Jahore, victorious from their bicycle and foot march down the Malay Peninsula, against valiant but outnumbered and outgunned Commonwealth forces. Six weeks were required to breach the defenses along the Straits and then the defenders were thrown back along the north, west, and east perimeters, toward a city shelled and bombed unmercifully. Capture of the island's strategic water reserves at MacRitchie Reservoir, on 12 February 1942, forced capitulation within three additional days. Singapurans, seventy-six percent Chinese by extraction, remember the ignomous fall and the ruthless Japanese occupation that followed. With liberation of the island in August 1945 came a time of uneasy reconstruction, again with crowded urban slum dwellings and poor public health conditions. Careful colonial administration and the selfless drive of Prime Minister Lee Kuan Yew set the stage for the amazing success story that has followed. Lee, a British-educated Straits Chinese of socialist leanings, was able to thwart communist infiltration and conduct a carefully orchestrated shift away from the entrepot trade to a labor-intensive economy of development. Lee remains Prime Minister to this day, 21 years later. What one sees and hears on the streets of Singapore is an unexpected and vigorously compatible mix of semi-autocratic socialism and unchallenged capitalism.

Capitalism provides the steam of the economy and socialism drives the sociological development of the Republic. The 1976 population was 2.3 millions, making the island one of the world's most densely populated nations. The overcrowded slums of 1960 have given way, one by one, to high-rise New Towns, such Nee Song, Bedok, Jurong, Clementi (named for a former British governor), Woodlands, and Ang Mo Kio. The names themselves bear witness to the diverse ethnic mix that is Singapore: 76 percent Chinese, 15 percent Malay, 7 percent Indian and Pakistani, and 2 percent "other."

The New Towns, along with freeways, port developments, reclaimed land, airports, military bases, industrial parks, and a striking high-rise central business district have all been constructed by the unique Singapuran drive—literally nothing stands in the way of development. Development of the island, obviously a favored project of Prime Minister Lee, is overseen by the Jurong Town Corporation (JTC), one of four major statutory bodies of the Republic. JTC, founded originally to create Jurong Industrial Estate, the country's first centralized, job-creating, manufacturing, and assembly venture, has grown to become the central planning bureau of Singapore. The JTC plans, directs, and manages industrial development, having established 17 of these estates by 1975. Additionally, in order to provide adequate facilities for factories and to place the factories near the people (Singapore is glutted with autos), JTC has control of the master plan for urban development of the Republic. The plan is maintained on 10,000-scale topographic sheets and leaves nothing to the imagination. Critics complain that the plan is too rigid and leaves no room for environmental trade-offs or recognition of geologic conditions on the island. This is virtually true! The urgency with which the Republic is developing housing and industry, with its infrastructure of ports and highways, calls for a massive and directed effort. There is little chance for modification, once the projects have been planned.

Geology as Practiced in Singapore

The *Geology of the The Republic of Singapore* was published in 1976 by the Public Works Department (PWD) of the national government. The volume, with an excellent set of six 25,000-scale, color geologic maps, sold for $40 and has been out of print since 1979. I fortunately obtained a facsimile copy of the text, and a colleague found some remaining sets of the maps at the Mapping Branch of the Ministry of Defense, at $28 a set. The mapping was a forward step from the previous reconnaissance-level studies, first published by the renowned J. B. Scrivenor (1924, 1931) and by Mrs. F.E.S. Alexander (1950). PWD geologists Lee

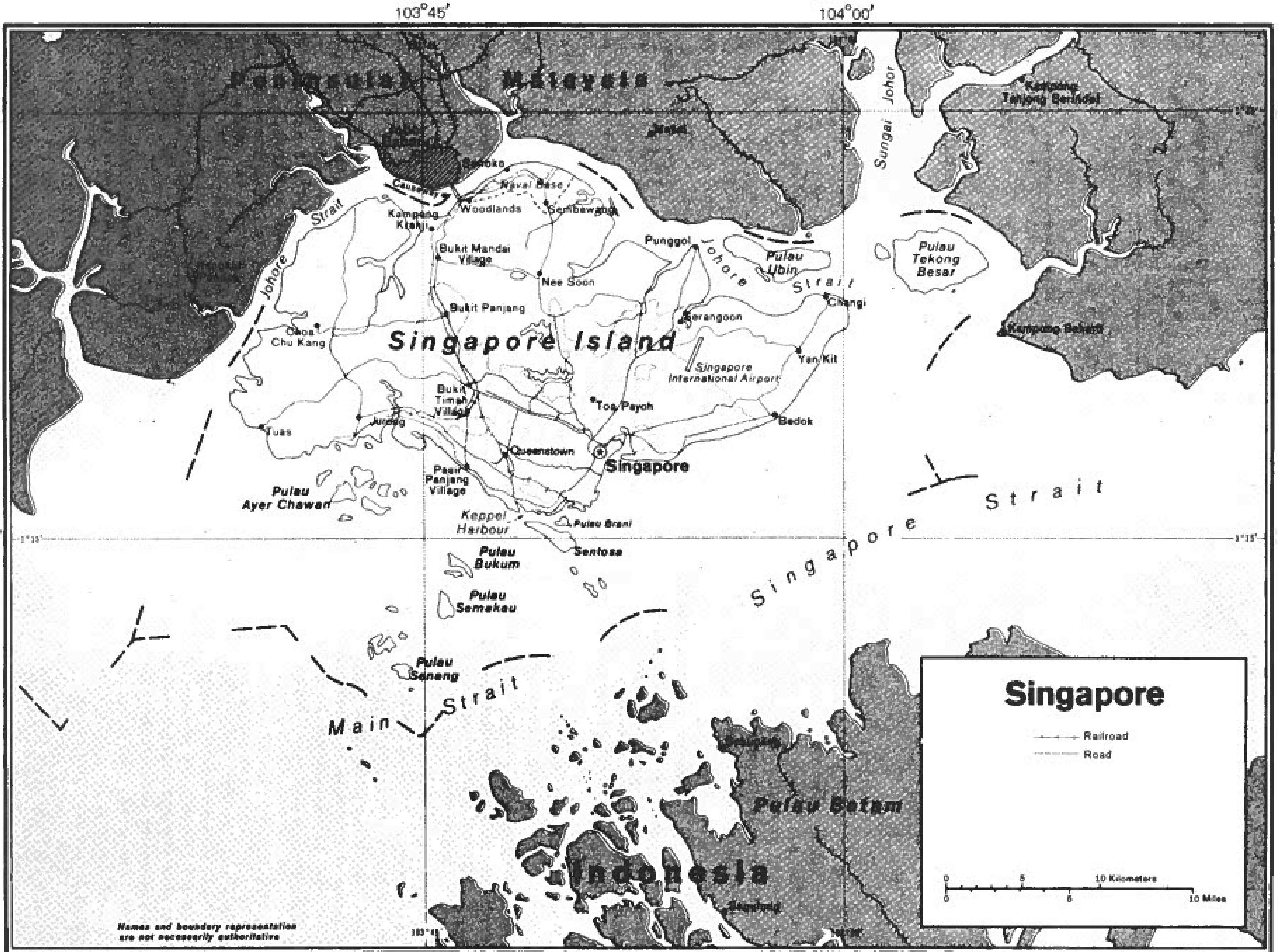

Figure 1. Index map of the Republic of Singapore (from U.S. State Department).

Figure 2. A portion of the Central Business District of Singapore City. The view here is to the southwest, from the Peninsula Hotel, across the Singapore River filled with lighter junks and lined on west bank by the fast-disappearing colonial-era brick and stucco buildings. Buildings, often taller than 50 stories, are founded here on piles driven through relatively soft Quaternary marine clay soils to sedimentary bedrock of the Jurong Formation. Bedrock is at variable depths, often in excess of 40 m.

Kim Woon and Loy Wei Choo were instrumental in preparation of the 1976 monograph, along with New Zealand and United Nations geologists. Interestingly enough, both Messrs. Lee and Loy vigorously claim that they are "classical" geologists and lament that they did not have the opportunity of academic training as engineering geologists. To this date, Singapore does not train its own geologists, the nearest geology department being at the University of Malaysia in Kuala Lumpur. To the author's knowledge, Messrs. Lee and Loy are the only government geologists involved in urban development of Singapore. A small community of geologists is to be found in Singapore, mainly involved in petroleum and mining ventures and siting of ofshore drilling structures.

Geology of Singapore

Singapore is divided roughly into three geologic terranes; the Jurassic-aged Jurong Formation of the western third, the pre-Jurassic Bukit Timah (Tin Hill) Granite, and the even older Gombak Norite of the central third, and the curious fans of the Old Alluvium, at the eastern third of the island. Other minor units have been described, mapped, and named, but these three main units provide the greatest impact on development of the island.

Bukit Timah Granite is found in a completely weathered state over a good deal of the island, often to depths of 20 m or more below hilltops. At other locations, the same unit, under a lateritic regolith of weathered rock, is found in an unweathered state and is furnishing nearly all of the crushed rock and riprap requirements of the Republic (Fig. 3). According to the *Straits Times,* 2.2 million tonnes of granite aggregates were produced on Singapore in 1978. Additional, undetermined tonnages come across the famous Jahore Causeway from Malaysia; producers there preferring the quick-paying Singapurans to their own developers, causing some degree of concern to the Malaysian government.

The scheme of national geologic mapping has identified granite by origin, and hence, developers operating on much of the granite terrane are often surprised to find a sequence of weathered soil of granite to depths of 15 or 20 metres. A.L. Little's (1969) classification of residual tropical soils by degree of weathering is quite applicable in Singapore.

The Jurong Formation, named by Scrivenor (1924), is a complex series of brightly colored and folded, faulted and weathered sandstones, mudstones, conglomerates, and interbedded tuffs and spillites (Fig. 4). Most of these Jurassic-aged rocks, as exposed by open excavations, cuts, and site grading, are machine excavatable.

The massive coalescing fans of the Old Alluvium supply the island with all of its fine aggregate needs (Fig. 5). The *Times* reports that about 1.2 million m^3 of sands were produced from island "quarries" in 1979, an increase of about 48 percent over 1978. The largest of the quarries, the Bedok sand pit, produced 74 percent of the island's requirements for 1979. This mammoth pit covers about 1.22×10^6 m^2 with a rim periphery of 5.1 km and a bottom periphery of 4.7 km.

Figure 3. Bukit Timah (Tin Hill) Granite as exposed in the Seng Kee Quarry, largest of the Republic's many aggregate production sites. This view shows the weathered, lateritic regolith with its characteristic "core stones," familiar also to geologists visiting Hong Kong.

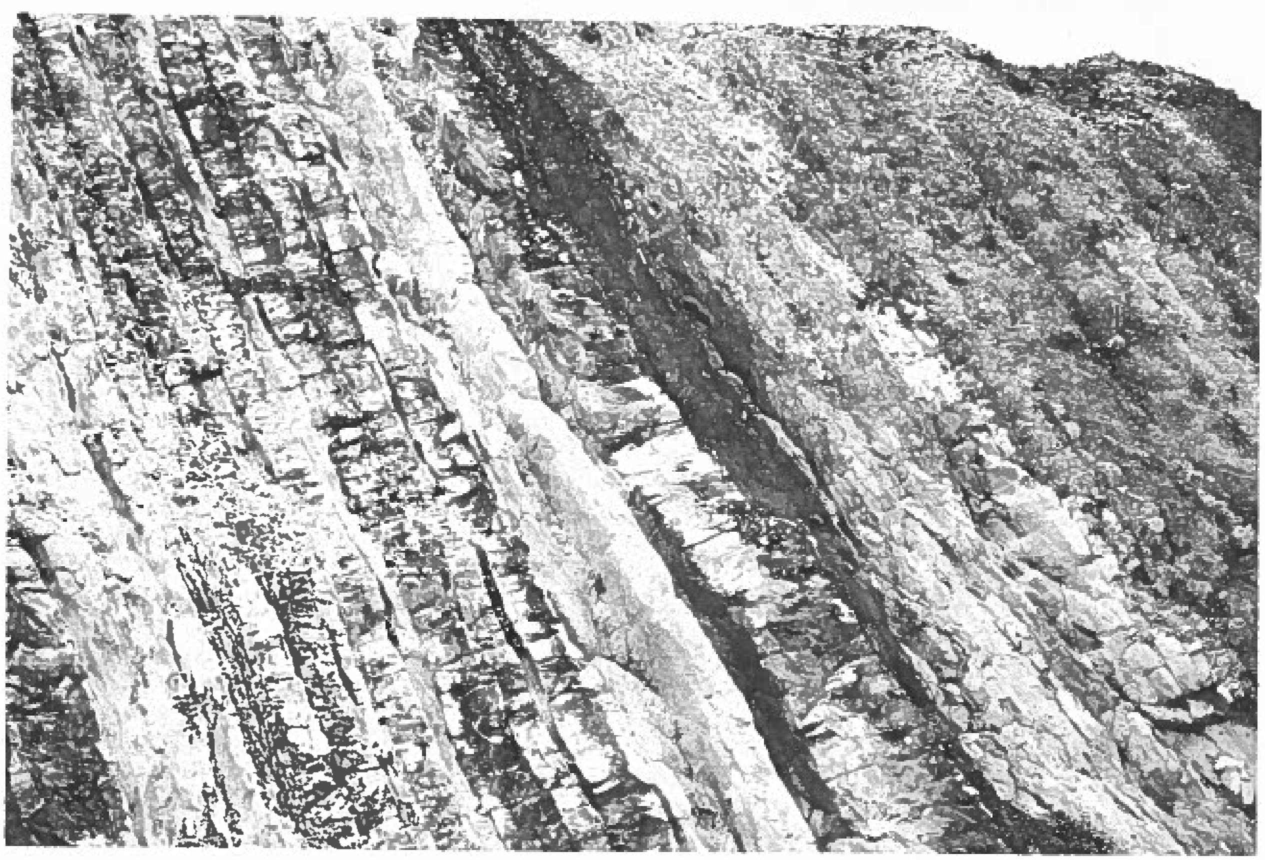

Figure 4. A characteristic exposure of Jurong Formation fine sandstones, mudstones, and interbedded tuffs, as exposed in a subdivision off Clementi Road, at grid coordinates 214340. Individual bedding thickness here ranges from about 10 to 20 cm.

Old Alluvium is usually a clayey, silty sand, with little variance from that gradation. Apparently the source of the fans was located relatively far north on the Malaysian Peninsula, with the fans spreading outward to the sea along the west coast of the peninsula and across what is now the Straits of Jahore, to the south. Rare are the particles in excess of 20 to 40 mm. The clay and silt fractions are largely the result of decomposition of feldspars and hardly any of these minerals are now found intact in the alluvium. The clay content gives the alluvium a cohesive character and relatively large amounts of clay and silt are retained as the sands are washed. Washing is carried on by government decree, apparently to avoid later contamination of concretes. Falling-head, field permeability tests conducted at the Bedok quarry in 1975 indicated coefficients in the range of 5×10^{-5} to 1×10^{-7} cm/sec, depending on the weathering grade of the sands.

Literally hundreds of active and abandoned sand quarries dot the landscape of the eastern third of the island. These quarries have sprung up in what were the coconut and rubber estates of colonial days. The peculiar nature of the Old Alluvium sands, with their weathering-produced clays and silts, makes for vertical cuts of up to 35 m of depth. I was told that this depth was the maximum allowed by government regulations. Added to this surprise was the case in which a 15-m vertical cut of a dry, operating pit stood separated by less than 10 m along a face some 60 m in length, from an adjacent pit filled with runoff. Not only was the dry-pit face seemingly stable, but it was dry! In addition to the stability contribution of the cohesion represented by the products of weathering, there may be some additional stabilizing negative pore pressure in these sands.

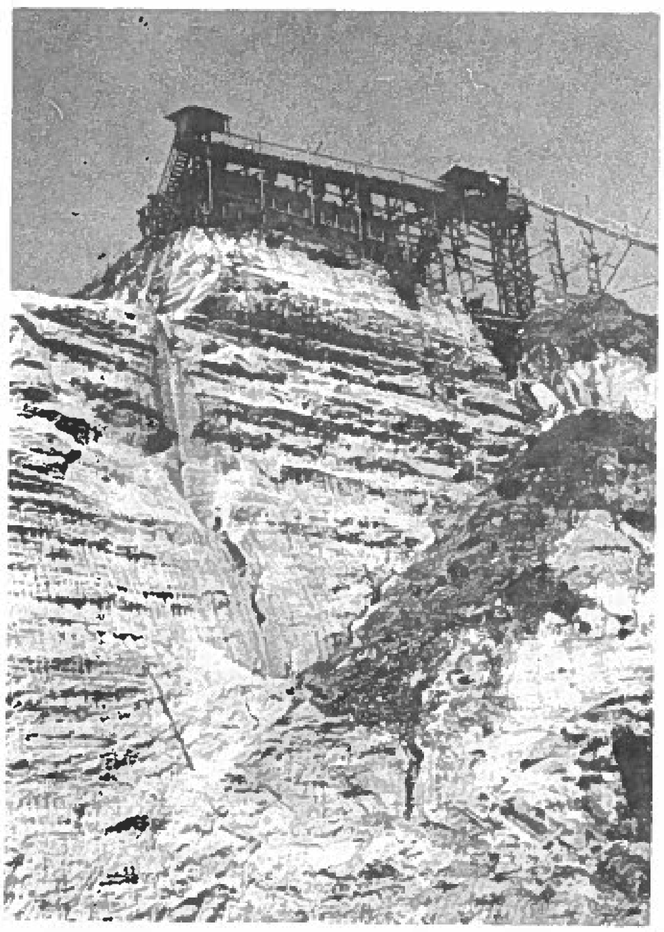

Figure 5. One of the striking sand pits or "quarries" of Singapore, located on the great fans of the Old Alluvium, of probable Pleistocene age, but lacking fossils to date. Pit operators carry many of these operations to the maximum-allowable depth by government regulations, 35 m. Vertical faces are maintained in these silty, clayey sands, in which the fines have been produced through tropical weathering. The sands are pumped to washing screens using slurry pipes.

Foundation Treatments

Geotechnical engineers are represented primarily by two firms, one of Japanese control and the other a branch of a Thai firm. A few foreign geotechnical companies supply consultation to the oil-field and offshore drilling activities in Southeast Asia. On-shore foundation explorations are carried on by drilling companies, mainly subsidaries of the pile foundation contractors. Those firms that do practice geotechnical engineering do so as a combination of foundation contracting and associated soil testing. Although their management personnel are generally heavily committed to the foundation construction activities, several prominent engineers are well-trained, geotechnical specialists, many with American graduate degrees.

Because of the dominance of the piling contractors and the overwhelming haste with which all structures appear to be conceived and constructed, one seldom finds deviations from the use of driven piling. Prestressed, concrete piles, introduced some 20 years ago, are fabricated at Hume Industries on the island and are driven by Japanese, diesel-powered rigs. Mammoth, concrete-weighted, reaction-frame, proof tests can be seen at numerous locations across the island. The tests are generally completed while the remainder of the piles are driven with fury. Japanese steel, H-beam piling are used in a far lesser number, possibly when cutoff considerations are present in some of the harder members of the Jurong Formation.

Drilled caissons (cast-in-place piles) have made a limited appearance over the past few years and are now installed in the 60 and 90-cm diameter varieties, mainly with American-made rigs. As in the southwestern U.S. usage, the caisson holes are fitted with site-fabricated, steel cages and concrete-poured. The caissons are most popular in the developing hillsides just to the immediate north of the Central Business District (CBD) of Singapore City. Here the topography and clay-rich nature of the weathered Jurong rocks preclude ground water within normal foundation depths.

In the Central Business District, high-rise construction has broken the 54-story record, and tie-back anchors are popular to retain vertical basement excavations, cut against tight property lines. Foundation conditions in the CBD are highly variable due mainly to Quaternary erosion of the Jurong stratigraphy along the south shore of the island. Relatively firm Jurong strata can be found within 5 to 10 m of the ground surface in some instances, and, in other locations up to 35 to 40 m of soft marine clay will be found to underlie a property. All of these changes can occur in the NE–SW breadth of the CBD, less than 2,000 m. The 45-story Raffles Tower, on Battery Street, under construction during my visit, featured a mat foundation placed on 100 long-ton (9.96×10^5 N/m^2) sandstone horizon, requiring blasting for removal to basement grade. I inspected some of this waste rock in a disposal area near Bedok and noted it to be a well-cemented, purplish and buff, banded, hard sandstone.

Competition among the foundation contractors is becoming intense. A joint-venture between Fondadile and Franki, represented by an Italian supervisor and a Thai crew, were drilling next to my hotel (The Peninsula) in Singapore City, for the purpose of bidding on the use of 1.5 to 2.0-m (diameter), poured-concrete piles. The crew had experienced thickness variations of up to 13.5 m in the marine clay below the site and had carried the exploratory borings (116-m borings with 78-mm, triple-tube core barrel) to depths of 51 m without encountering hard rock such as found below the Raffles Tower site, some 800 m distant.

Small structures on soft ground have been traditionally supported by hand-trimmed, driven, small-butt (10–20 cm) timber piles (Fig. 6). Since most construction is quite substantial, either government-built facilities or commercial high-rise buildings, the small-diameter, timber piles appear to be used only on water-control structures such as canals. These piles are driven by backhoe-mounted devices.

Figure 6. Workmen preparing the traditional small-diameter, driven timber pile foundation for a canal along the Ulu Pandan, a natural stream-turned drainage channel. The Kuala Lumpur rail line passes overhead, supported on a sheet-pile coffer cell, also common to Singapore. Typical government high-rise public housing of the Ghim Moh Estate are in the background.

Coastal Land Reclamation

Typical of Singapore accomplishments, much of the Old Alluvium removed in site grading and sand-pit operations has been used at an astounding rate to increase the size of the island at its shoreline and in some minor estuaries Between 1966 and 1975, Singapore increased its size by about 6 km^2 using these sands. Today, one can see the site preparation for industrial development, about 3 km SW of Yan Kit (see Fig. 1) being carried on by two giant bucket wheel excavators, feeding their spoil into a conveyor system that wends its way for 5 km to a placement area and barge-loading facility at the Bedok coast.

The Bedok quarry itself is the scene of a continuous queue of 5-m^3 lorries; perhaps 25 to 35 lorries are in the process of entering, loading, or leaving at a given time, each stay averaging about 20 minutes duration. I estimated that about 2,400 to 3,000 m^3 of sand were leaving the quarry daily.

Waste Disposal

Several refineries are located by environmentally and safety-planned dispersion on islands lying within a few kilometers of the south shore. Singapore naturally uses fuel oil to incinerate its solid waste (since 1977) and to generate electricity (1030 MWe). Construction waste, however, along with utility generation fly ash, bottom ash and boiler scrubbings, and some trash collection from outlying areas, are disposed of in three landfills operated by the Ministry of The Environment (MOE). The landfills are located on tracts of land along the north and northwest coast and are relatively near the Straits of Jahore and at the down-gradient ends of watersheds. The landfills appear to be reasonably well designed and subjected to compaction and application of daily cover. In 1975, Singapore generated about 1.62×10^3 tonnes/day of solid waste.

Water Supply

Until recent years, some 60 percent of the potable water used on Singapore came by way of a pipeline placed along the Jahore Causeway, and it transported the supply from Singapore-operated reservoirs located in Malaya. With the remembrance of the surrender of 15 February 1942 still fresh in the minds of citizens, Singapore's PUB has relentlessly constructed impoundments, especially to collect the monsoon rainfall of November to March and May to September. Aquifers are not known or expected to be found on Singapore; even the Old Alluvium is too choked with silt and clay to yield water. Consequently, a good portion of the island has been set aside as combination nature reserves, catchment areas, and military maneuver grounds.

Seismicity

Structural engineers have been designing without the benefit of a formal seismic risk assessment of any kind. Quaternary displacements have not yet been detected on Singapore. The nearest instrumentally recorded epicenter, appearing in the World Wide Seismic Network Catalog of 775 events (U.S. NOAA, Boulder, Colorado) lies some 450 km to the SW, on Sumatra. The date of occurrence was 24 December 1929. The magnitude and depth are imperfectly known but epicentral depth was probably less than 70 km. The author and Dr. Edward Chiburis compiled a seismic risk assessment for the island—there being no apparent reason or means to be more site-definitive. The result of this assessment has been that Singapore is not entirely without seismic risk, but that recurrence interval and attenuation estimates are now available. The main source of seismic motion is apparently the subduction zone paralleling the SW coast of Sumatra and dipping beneath that island, to the NE.

On occasion, one can observe thin (10 to 45 mm) clay dikes in the sand quarries of the Old Alluvium. Most of these can be traced for tens to hundreds of metres. Where exposed, and, depending on their grain size, they tend to stand up as erosion-resistant or (less frequently) erode out to form striking fissures. Most are oriented with strikes closely paralleling N30E and are vertical. The N30E strike is the dominant fault orientation on the island; most of the known faults occurring in the Jurong Formation. Of 31 such sedimentary dikes noted by the author, only one displayed any obvious displacement; 1.0 to 1.5 m of right-lateral, strike slip with a small, downthrown component on the east side, along a 75-degree SE dip.

The prevalence of such features, together with the generally fine (silty clay, by evidence of one laboratory hydrometer test; 72 percent passing No. 200 sieve) filling, the evenness of strike, and the continuity of length suggests that the dikes were formed by liquefaction of various fine strata at depth during extreme levels of ground shaking. The time during which this ground shaking occurred was probably when the Old Alluvium had consolidated sufficiently to become brittle enough to fracture. This would also be late enough so that the consolidation had not progressed enough in the finer-grained strata to either dewater them completely or to have created a density incompatible with liquefaction. An estimate of this age is between 25,000 and 50,000 years, BP. The N30E strike may indicate that faulting at that time was in activation of the same set of faults that are found commonly in the Jurong outcrops and in excavations in the western third of the island.

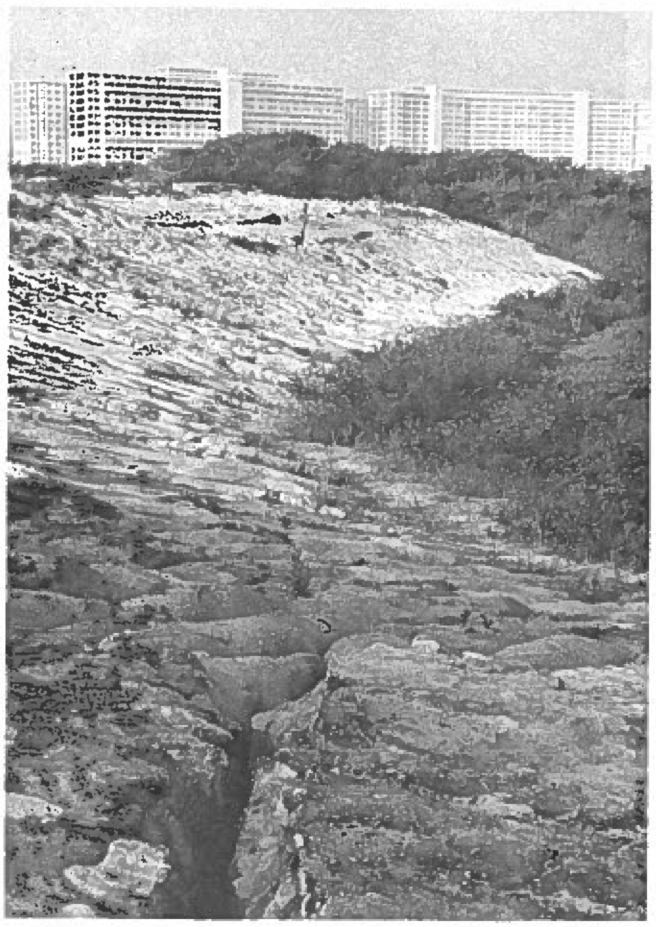

Figure 7. Eroded and resistant sand dikes of the Old Alluvium, as exposed in the Bedok sand pit, with Bedok New Town (a community of a quarter-million) in the background. The eroded dike is the more striking of the features at this location and extends more than 180 metres to the sharp fracture lying just short of the brushline in the middleground. The dike is oriented at N30E, a common fault attitude in the Jurassic-aged Jurong Formation, exposed over about one-third of Singapore. One of the resistant sand dikes lies just to the right of the eroded dike.

Summary

Perhaps the reader has wondered why geologic constraints have not entered into my discussion. There are very few such constraints. The unique features of Singapore geology, when known, can be used to predict the expected effects on construction. Many of these tricks have been learned by the civil and structural engineers practicing on the island and have been overcome, so to speak, by brute force and stout engineering. There is little doubt that engineering geologic knowledge can and should be used to save the Republic precious development funding—if the geologists can work rapidly ahead of the dozers! Slope movements on Singapore appear to be limited mainly to *earth slumps* in residual soils of the Jurong Formation. Since the tropical weathering process produces almost exclusively kaolin and its close cousins, clay soils are not notably expansive. Depositional or formational processes for surficial soil units have not produced collapse-prone soils and carbonate rocks are essentially missing from the stratigraphic column on the island—hence subsurface cavities are unknown. Perhaps the most dangerous geologic condition from the standpoint of foundations is the extreme variability of the depth and lateral extent of the marine clays and stratigraphic variability of folded members of the Jurong Formation. This means that inattentive foundation exploration could create settlement or bearing capacity-related problems for heavy structures or facilities with large-area foundation imprints.

Singapore is an exciting new nation—its geology is colorful by virtue of its tropical weathering; Prime Minister Lee's crews are continually laying open the Earth for the joy and delight of the visiting geologist. Don't you dare pass Singapore if you are in Southeast Asia or are Down-Under!

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Presenting Geology to Engineers

Howard A. Meyerhoff, Professor Emeritus, The Pennsylvania State University
(now, Tulsa, Oklahoma)

Whether some reflections of an Emeritus Professor of Geology on engineering geology merit the consideration of the readers of this newsletter, I have left to the discretion of the editor. In presenting them I have flouted all the rules. I have made no survey of the courses in engineering geology currently taught in schools of engineering, nor have I attempted to gather statistics of student enrollment in such courses. I have not looked at a textbook on the subject since I retired from teaching thirteen years ago. I am writing from four years of teaching a course labeled "Engineering Geology" and from consulting experiences in engineering projects that started with the construction of the Guajataca dam in Puerto Rico more than 50 years ago. I believe some conclusions drawn from these assorted experiences possess a validity which may be worth recording. They cover a wide spectrum.

The Academic Problem

(1) Engineers don't take geology:

Generalization is dangerous, perhaps worthless, when it lacks a broad statistical base; but it was my experience that fewer than five percent of the civil engineers registered for the course in engineering geology at the University of Pennsylvania, and twice they were outnumbered by chemical engineers. The course was optional, and the reason given for low enrollments were understandable. The addition of courses in the humanities to the basic requirements for the degree in engineering left little room for options. The question which logically follows is whether the relation between geology and engineering is so casual as to be optional, specifically in the civil engineering curriculum. The answer is not as simple and clear-cut as one might expect from a geologist.

(2) Engineers don't like geology as commonly taught:

The course which I inherited seemed to be typical of courses generally offered in the subject. Essentially, it was instruction in elementary geology partly adapted to situations commonly encountered in engineering projects. Although it had been taught by a talented young geologist, I found the textbook and the course based on it insufferably dull for students already trained in soil mechanics and strength of materials, with little prospect of making it more attractive by shifting to other available texts. So I faced a new question: Do engineers profit from this kind of geologic instruction? My answer is an unequivocal "NO." Basically, such a course is aimed at teaching the elements of physical geology to students not planning to be geologists, with the possible exception of those studying to become mining engineers. Other engineering students have no intention of entering geology as a profession or engaging in its practice; and from the courses in engi-geology as currently presented, they are exposed to the hazard of thinking they have learned all they need to know to solve geological problems encountered in engineering practice. This hazard too commonly finds expression in faulty, expensive, or even disastrous solutions to field problems. The training of engineers in geology should concern itself with teaching the recognition of geologic problems which call for the expert advice of professional geologists.

Range of Field Problems

(1) Floods

A treatise could be written on the engineering problems posed by floods, and the ravages of recent floods in the Appalachian region and elsewhere in widely scattered parts of the United States have shown the need for more intensive geologic studies to minimize the risks to life and property. We are hearing more about 10- and 100-year floods but, like California's weather, the unusual flood has become more usual than unusual. The elements, abetted by the works of man, remain oblivious to theoretical time tables. Facts, figures, and formulas governing stream flow in relation to volume, gradient and velocity are well known and, in general, are effectively applied; but the importance and limitations of infiltration are commonly overlooked. The paving of spacious shopping centers here in Tulsa, for example, has so reduced infiltration that two sections of the city are now subject to disastrous flash floods in heavy rains.

The insidious ways of flowing water, and especially of turbulence, are not always appreciated. Flood waters from the hurricane rains of "Agnes" sapped the sandy underpinnings of a well-built but too shallow protective riprap wall, with the loss of a section of road and a threat to fringing dwellings, in the Susquehana drainage basin of Pennsylvania. Similarly, a bridge pier in one of Oklahoma's rivers suffered downstream undermining and irreparable damage where the sand fill was too deep for the footings to reach bedrock. In Vermont, flood waters re-excavated a preglacial channel overnight and left a new steel bridge in splendid isolation. The superficial postglacial channel was destroyed, and return of the stream to the pre-flood course was impossible. The bridge had to be dismantled and relocated.

One blunder in bridge construction which I never expected to see duplicated elsewhere was made in the name of economy, which proved false. At Arecibo, Puerto Rico, the Rio Arecibo was bridged with the shortest possible span in the river's flood plain, and the approaches were built up to keep the highway clear of the high waters of the rainy season. The road embankment served as a dam which left the channel-wide opening at the bridge as the only outlet for flood waters. It took three losses of the bridge to convince the road engineer that it was more economical to sacrifice the more cheaply restored approaches. Now, half a century later, I find the same blunder repeated in the outskirts of Tulsa.

Except where life may be endangered, engineering response to flood hazards become largely a question of economics; but even this question is rarely answered by the quotation submitted in the lowest bid for a specific project. Any outdoor structure must be fully adapted to its physical environment, which is controlled by surface and subsurface features and by the geological agents modifying them. Civil engineers are well trained to deal with normal and obvious features, but there is no reason why they should be expected to deal with the less obvious or abnormal. Their responsibility, however, is to recognize the possibility of obscure or abnormal elements in any given situation and to seek expert advice in identifying and evaluating them in respect to design and cost. Clearly this should be done before bids are submitted and contracts let.

(2) Other Water Problems

Perhaps the following experience is one of a kind, but it may be worth recording. In the Dominican Republic the development of a new banana plantation required the conversion of a long-used country road to an all-weather road for heavy truck traffic. The road was in the floodplain of the Rio Yaque del Norte, with no solid bedrock within miles. One section of the road paralleled an overflow channel of the river for several kilometers, and at a seemingly safe distance of 40–60 meters. When the road was put to heavy use, some caving occurred, but it was regarded as a minor nuisance until a loaded truck abruptly dropped 4 meters into a hole 12 m long and 7 m wide. Investigation of the cause revealed a humid-tropical phenomenon. Between high water of the rainy season and low water of the dry season, the water level in the river and its subsidiary channels dropped 6–7 meters beneath the sun-baked silt of the surface. The alluvium at depth remained saturated and, with withdrawal of the water pressure from the channel, flowage of the silt toward the channel apparently was triggered and abetted by the heavy truck traffic. Although the flowage was differential and channeled, prediction of other sites of prospective collapse was little more than guess work, and relocation of the road was recommended.

Water projects in limestone terrane present special problems. The Guajataca reservoir in northwestern Puerto Rico is in a karst area which required careful study of sinkholes and other solution features. The holes were so effectively sealed over the entire reservoir site that the water loss from the filled reservoir barely exceeded the calculated loss from evaporation. Unfortunately, however, no thought had been given to leakage in the irrigation canals, where a loss of 85% was registered until they were sealed and lined. Nor was it realized that the local carbonate rocks would lose their coherence until the dry limestone designated for use in the core wall of the dam turned to mush during wet transport.

(3) Foundations

Soil and rock mechanics provide much of what the engineer needs to know about foundations for nearly all kinds of construction, but soils, rocks, and rock structures have insidious ways of fooling engineers and contractors. Experience and experiment have licked most of the problems presented by postglacial hydrated, or saturated, clays, as well as permafrost; but hidden—and common—hazards still trap the unwary.

In a western Massachusetts city, an uncharted peat lens was encountered in a post-glacial terrace as the foundation was being laid for a new school. The topographic limits of the terrace and the property lines precluded changing the location of the structure. The construction of a bridge across the weak zone finally solved the problem, but raised havoc with cost estimates, bids, and appropriations. Potentially more serious was the presence of an all-but-hidden peat layer in the foundation site of a new hotel-office building complex in Washington, D.C. The deep excavation for the substructure offered an excellent exposure of the poorly consolidated Greensands, and I made the most of the opportunity to examine it on a Saturday afternoon when no work was in progress. Some chunks of dark brown "dirt" in the floor were found to be lignite from an undetected bed penetrated by one of the piles. The deposit was a thick lens which entered only one corner of the lot, but it had all the potential of providing the nation's capital with a Leaning Tower of DeeCee.

Dramatic in a small way was an incident in western Massachusetts, where county commissioners decided to pave and widen an old dirt road, which skirted a small meadow surrounded by rock walls. Rather than blast, the widening was done by ballasting the edge of the meadow. One of the first loaded trucks that used the road was tilted into the meadow, where it disappeared before it could be salvaged. The meadow was an old incompletely filled glacial pond surfaced with a thick mat of vegetation. It took 30 truck loads of stone to provide a proper base for the road.

The instability of houses built on sand has been proverbial at least since biblical times, but the eternal proof of the axiom was impressed on Army engineers in a World War II experience. Plans called for the conversion of a warehouse to a forge shop containing three banks of hammers. Information was sought and obtained on the foundation of the structure, with advice to relocate the heavy hammers and to deepen the footings so as to bypass 12 feet of superficial, uncompacted sand and to penetrate compacted sand below the water table. Bedrock was too deep to be reached economically. The advice was not followed because, as was explained later, time was vital, and it would have taken several weeks to get approval of the added expense from Washington. Only a few weeks after operations started, two of the three heavy hammers sank as the concrete floor supporting them bowed and rendered them useless, and the Government faced 19 law suits filed by residents in the area, whose dishes bounced off shelves and tables, house walls were cracked, and sleep shattered as the hammers pounded in three shift operations to turn out carbines for the invasion of France. Although time may have been saved and much of the purpose of the operation had been served, the ultimate cost was 30 times as great as it would have been had the conversion been done in accordance with the geological advice.

(4) Geologic Structures

Much has been learned about construction in earthquake-prone regions, but ramifications of quakes are still underestimated and little of the information seems to have gotten through to contractors. Recent studies by the U.S. Geological Survey have revealed that horizontal ground motion in the San Francisco Bay area is considerably greater than was thought, and that fewer than 50% of the structures are sufficiently reenforced to withstand it. The collapse of overpasses across main highways in an earthquake in the Los Angeles area demonstrated the need for changes in design and steel reinforcement. The mass movement of structurally and lithologically vulnerable rocks along the main thoroughfare and in the Turnagain Arm residential section of Anchorage, Alaska, in the 1964 Good Friday earthquake was forecast by USGS geologists, but was disregarded and even ridiculed by local promoters. Hazards are great in regions where the geology is not well known. In the

Dominican Republic, for example, I had to condemn the proposed site of an irrigation reservoir because the preferred location was directly across the second most active fault in the Greater Antilles.

A few rock structures other than active faults present constructional hazards which are overlooked more often by developers than by engineers. Dip slopes in sedimentary rocks that are inclined toward lower topographic elevations are susceptible to mass movement ranging from creep to landslides, especially in poorly consolidated sections of alternating sandstone and shale. Houses and roads have been common casualties in this type of structural situation. The sites may offer an enticing view but an extremely uncertain future. Even in the absence of such sedimentary structure, scarps which approximate or exceed the angle of repose are treacherous for slides above and rock falls below.

The Communications Problem

If this recitation seems endless, it is no more than a fractional listing of situations faced by one geologist in more than 50 years of practice. Problems in shoreline erosion and construction, and in groundwater vagaries could be added, but I shall not extend the list. I will, instead, try to answer the question: How can the prospective civil engineer be trained to deal with the variety of situations he may face, whichever phase of civil engineering he may enter?

Obviously, he can't; and no competent geologist can pretend that he knows all the answers. The geologist merely knows how to seek them. All he can attempt to do is to train the engineering student to recognize a geologic problem when he is confronted with one. After I took over the course in Engineering Geology at the University of Pennsylvania, with only one prior experience teaching it as visiting professor at the University of Puerto Rico at Mayaguez, I concluded that the standard course in engineering geology fails in this fundamental purpose. Redesign of the course was circumscribed by the available textbooks and lecture-laboratory materials and equipment, but the direction the transformation should take was clear. The goal seems worth presenting.

(1) Except in the relatively few departments of geology which offer a specialty in engineering geology, the course available to engineers is generally regarded as a service course or an accommodation to an alien department. As such, instruction is commonly assigned to young assistant professors, who may be excellent teachers, but who lack varied and prolonged experience in the field, whereas the goal calls for instruction by senior members of the department—men and women with records of practical experience. This requires a change of attitude which is likely to encounter resistance; and, if it does, administration of the course should then be assumed by the Department of Civil Engineering.

(2) The method and content of the course should be dominated by case-problem presentation, in which subject matter may be taken up in the orthodox order of available texts, starting with rocks and minerals, rock structures and weathering, and proceeding through the geological processes of water, wind, ice, volcanism, and tectonics, with closely correlated topographic and geologic map interpretation. Texts and other pertinent reading matter, as well as laboratory materials and equipment should be used as adjuncts to cases presented in class and to problems given in assignments and examinations. These adjuncts should be adequate to illustrate the critical features of the cases discussed and to contribute to the solution of the problems assigned, whether maps, charts, tables, rocks, minerals, testing equipment, and so on.

(3) In Schools of Engineering, this kind of instruction should be recognized as basic and required, rather than as optional, in civil, mining, petroleum, and environmental engineering curricula; but it should be one of the terminal courses, taken in senior year, when students have acquired many of the engineering skills they will need in practice.

Conclusion

Obviously, the adoption of these recommendations will require a new look and a new attitude on the part of academic engineers and geologists, not to mention some travail on the part of textbook authors and publishers. My experience as a teacher and consultant, which stretches over half a century, has demonstrated the need for much more and much better communication between the two fields, for a substantial fraction of my consulting work has been in response to calls to solve engineering-geological problems after an engineering impasse was reached and, too often, after the damage was done. Now that "impact studies" have become an expensive way of professional life, collaboration is imperative; and to be effective, it must reach down into the undergraduate classroom but at a higher level than in the past.

As for the result, I can speak only for the brief period in which I changed the type of instruction at Penn from the standard sophomore text-laboratory elementary course to a senior-level case-problem presentation. The student response to the change was especially gratifying. Although the heavy course requirements in engineering kept the engineering student enrollment low, enrollees from landscape architecture left standing room only for auditors in the small classroom to which the class was assigned. That something had been learned came back to me in an examination, which was final both to the students and to me just before my retirement. The examination involved the identification and solution of problems raised by the proposed diversion of waters to the Rio Grande from the Colorado River system. On three of the examination papers—two by engineers—what apparently were my own forgotten words were given back to me: "When you tamper with nature, you damned well better know what you are doing."

Arkansas-Red River Basin Chloride Control Project

Seth Thomas Gay, Chief Geologist, U.S. Army Engineer District, Tulsa, Oklahoma

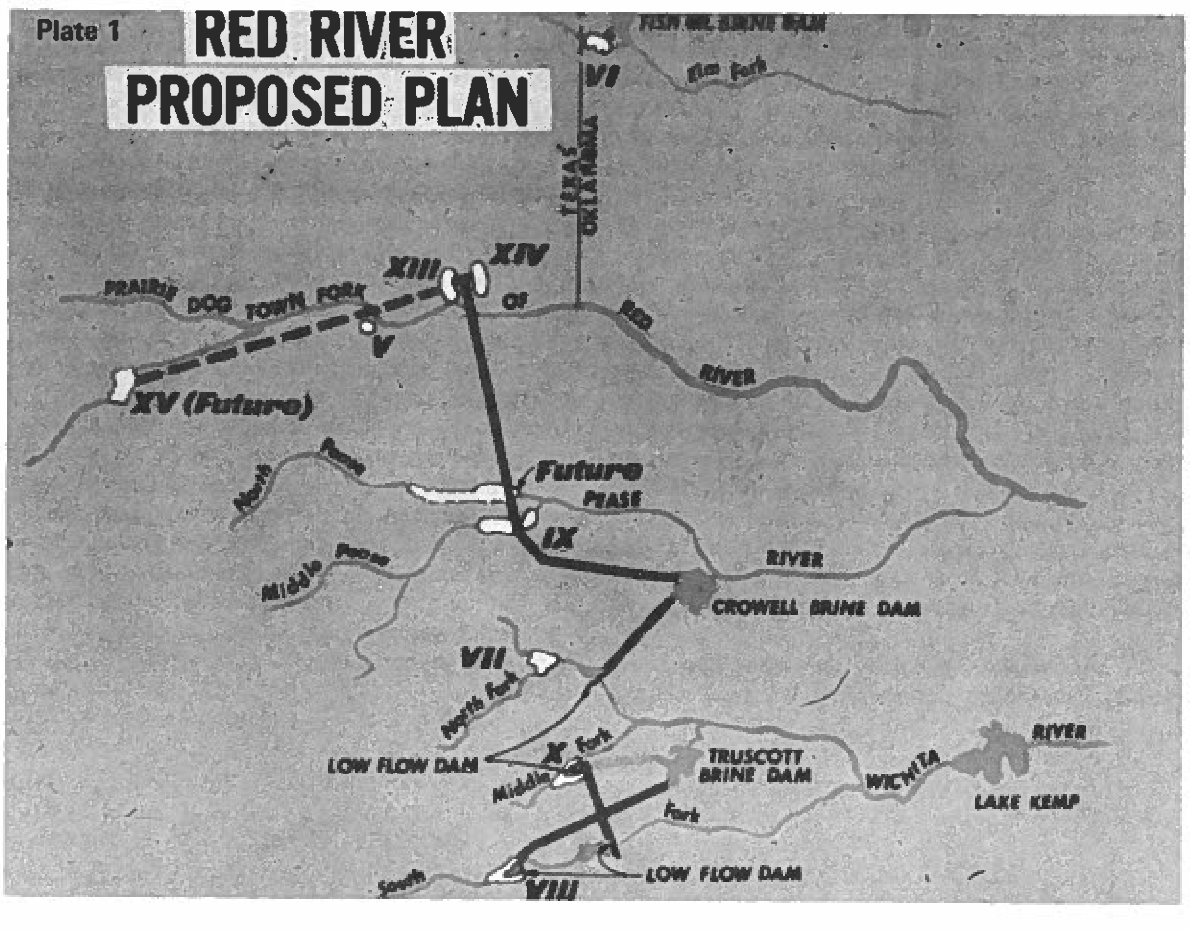
In 1957 the Public Health Service, under authority of the Federal Water Pollution Control Act, identified 15 principal sites where natural saline brines were being emitted, 10 in the Red River Basin (Texas and Oklahoma), and five in the Arkansas River Basin (Kansas and Oklahoma). In 1959, Congress authorized continuation of the study and directed the U.S. Army Corps of Engineers to examine various methods of controlling the natural salt pollution. In the 1960s, studies indicated about 34 percent of the salt in the Red and Arkansas Rivers came from human activity and from minor natural sources. Efforts have been made by the states of Oklahoma, Kansas, and Texas to reduce salt pollution from oil fields, mining and industrial operations. The remaining 66 percent of the salt is from natural sources: it results from ground water dissolving salt-bearing Permian rocks in the shallow subsurface, and the resultant brine is emitted at the surface as seeps or springs or by capillary action (salt flats).

The data presented in this writing is a brief summary of years of study by the Corps of Engineers, extracts from their hydrological and geological findings, and interpretations and layouts of their plans proposed for the control of brine pollution in the Arkansas and Red River Basins. The cooperation of many Federal, State, and local agencies as well as private firms and individuals has contributed valuable data to these chloride-control projects.

The Arkansas and Red River drainage basins comprise eight percent of the land area of the United States. The central portion of the Arkansas River and the entire reach of the Red River above Lake Texoma are being degraded by brine emissions to such a degree that the stream flows and associated ground water are unusable for most purposes. The principal goal of the Arkansas-Red River Chloride Control Project is to improve water quality by controlling salt pollution from natural sources in order to have enough water sufficiently clean in the right place at the right time to serve the range of human and industrial needs. To meet high water-quality standards at a reasonable cost required establishment of the following realistic criteria and principles: (a) control stream pollution from each natural salt source to the degree that the concentration at downstream points of use would not exceed an upper limit of 250 mg/l of chlorides; (b) achieve the desired degree of chloride reduction at selected checkpoints along the major streams in terms of specific quality, qualified as to percent-of-time the water should be usable; (c) control as much of the natural chloride pollutant as practical near the source for most efficient quality improvement.

Red River Basin Chloride Control

The Red River originates in New Mexico, crosses the high plains of Texas, gathers flows from Oklahoma, Texas, and Arkansas, and passes through Louisiana on its way to the Mississippi River. Approximately 90 percent of the drainage area is downstream of the major salt source areas. The natural chloride pollution occurs upstream of Lake



Texoma, a major multipurpose lake located in the approximate center of the basin. Nine source areas shown on plate 1 (Area XI on upper Red River is not shown) in the western portion of the Red River Basin emit most of the natural salt entering Lake Texoma. The terms salt, chlorides, and brines are interchangeable unless a specific quantity is defined.

Principal outcropping rock units in the Red River Basin emission areas are considered by various workers to be either Upper Leonardian or Lower Guadalupian in the Permian System. The general surface geology has been mapped by Dr. Kenneth Johnson, of Norman, Oklahoma, Corps consultant, and by Tulsa District geologists. These rocks consist of Permian strata that dips regionally at 5 to 50 feet per mile to the southwest into the large Permian Basin of west Texas and southwest New Mexico. Outcropping layers of gypsum, dolomite, and shale are interbedded with layers of salt in subsurface to the southwest, where the salt layers are generally more than 200 to 800 feet below the present land surface. Plate 2 shows the subsurface distribution of Permian salt along with the location of brine springs and salt plains that are causing similar pollution problems for about 300 miles along a north-south belt that extends from Kansas to Texas. Plate 3 shows the subsurface distribution of salt beds in the Red River Basin study area.

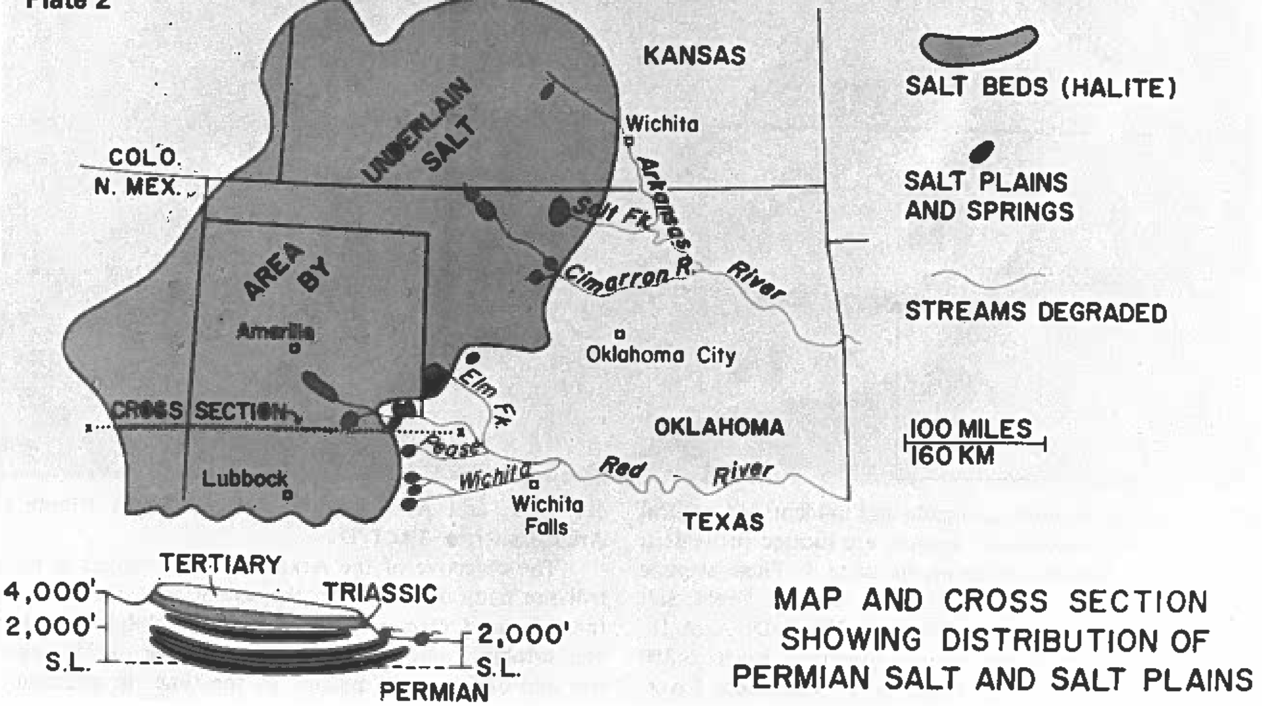
The total tons per day (T/D) of salt load has fluctuated some over several years of monitoring these salt loads. The difficulty in obtaining good control on monitoring this important part of the study is due mainly to complex measuring techniques, the large geographical area, the weather, and to the unusual geohydrologic conditions. The total average salt load for the Red River Basin is about 3,300 tons per day. Approximately 1,095 T/D is believed to be minor natural and manmade loads. About 429 T/D come from three primary source areas in the Wichita River (sub-basin), and 1,752 T/D come from the seven principal source areas in the remainder of the Red River Basin.

Based on the criteria and principles established for improving the quality of water, the Corps of Engineers recommended a collection system be installed at or near the emission sources. Area XI (220 T/D) was omitted from this plan as the study indicated it was not economical to collect brine from this source. Area XV (120 T/D) and a portion of Area IX (North Pease River) have been designated for future development. Basically the system, as shown on plate 1, consists of collecting the highly concentrated brine during periods of low flow as near the source as practical for collection and construction. The brine would then be pumped to brine lakes (Salt Creek, Crowell and Truscott) to be evaporated. Lake Texoma and Lake Kemp have been selected as major downstream contact points to check project effectiveness. The 250 mg/l chlorides is a measurable standard which is used to indicate allowable chloride concentrations and is the Public Health Service standard for municipal water supply. With the Wichita River portion of the project in place, about 360 T/D of the approximate 450 T/D emission in the Wichita River (sub-basin) will be controlled, thereby reducing chloride levels in Lake Kemp to 250 mg/l about 98 percent of the time. With the rest of the Red River project completed (including the Wichita Project), the water at Lake Texoma would meet the 250 mg/l standard for chlorides 94 percent of the time.

Arkansas River Chloride Control Project

The Arkansas River Basin comprises a drainage area of 159,000 square miles in Colorado, New Mexico, Kansas, Texas, Oklahoma, Missouri, and Arkansas. The Arkansas River represents 10% of the nation's surface flow. About 1,050 river miles below the salt source areas are degraded by chlorides. The average salt load from the basin passing Tulsa, Oklahoma, is 11,900 tons per day (T/D), which equates to a daily convoy of 476 "18 wheelers" to move that same volume of salt in solid form. Of the 11,900 T/D, 7,900 T/D are from the five identified natural sources and

Plate 2



MAP AND CROSS SECTION SHOWING DISTRIBUTION OF PERMIAN SALT AND SALT PLAINS

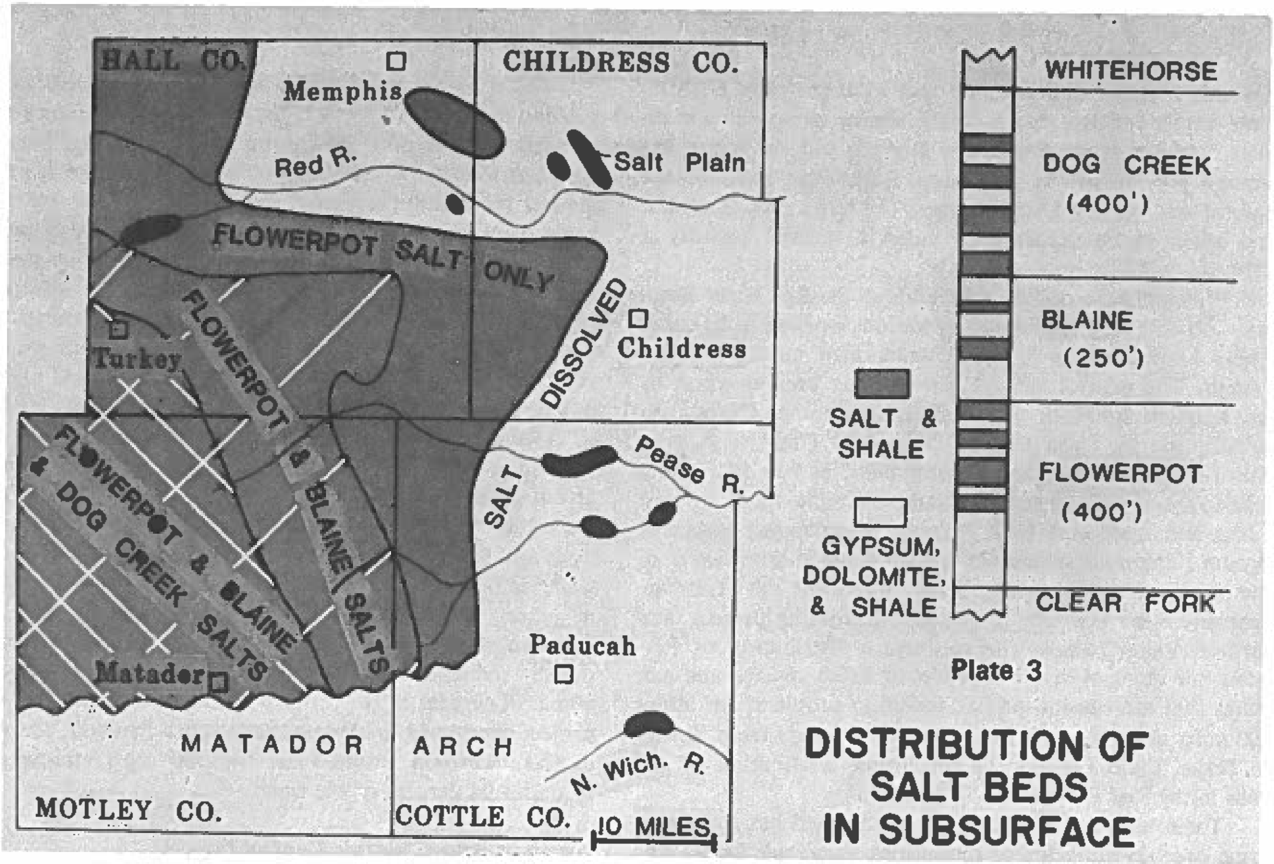


Plate 3

DISTRIBUTION OF SALT BEDS IN SUBSURFACE

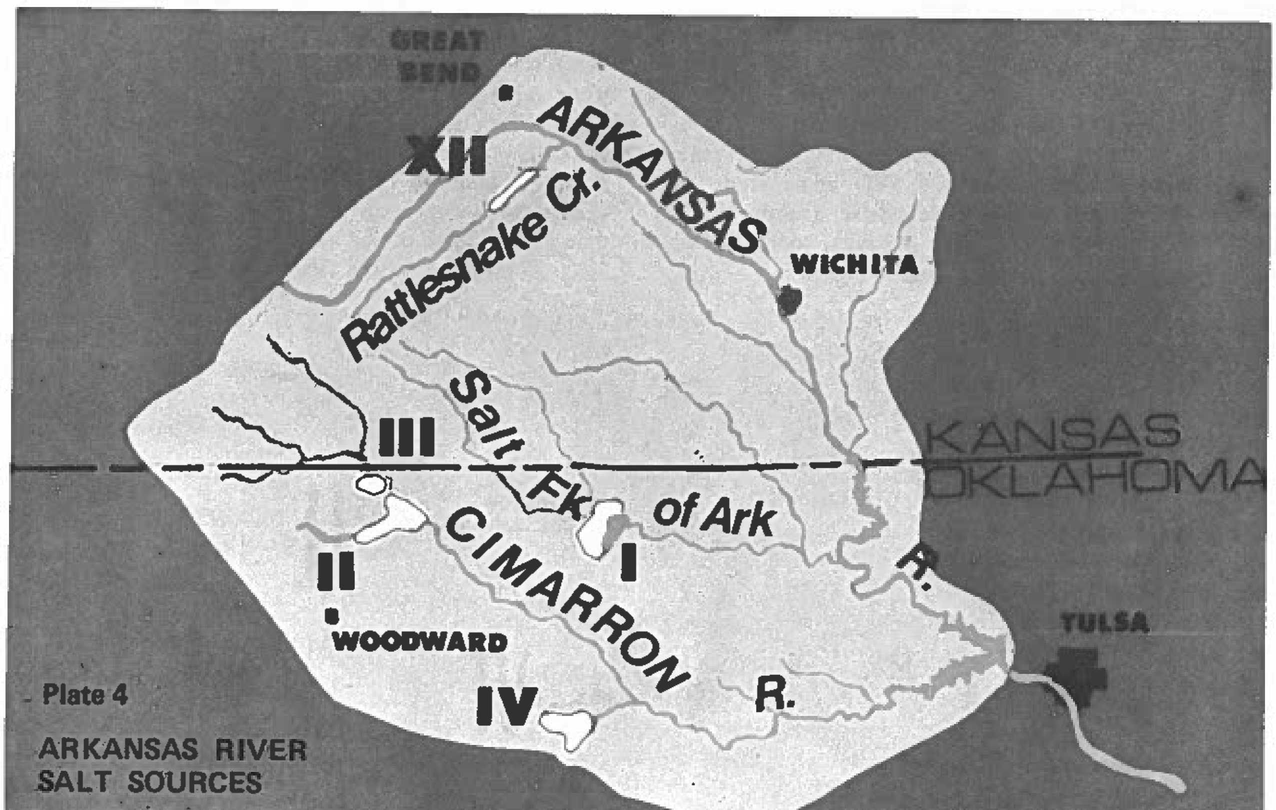


Plate 4

ARKANSAS RIVER SALT SOURCES

4,000 T/D are from both manmade and unidentified natural sources. The five natural salt sources are located in western Oklahoma and Kansas, as shown on plate 4. Their average daily emission of salt are as follows: Area I, Great Salt Plains, Salt Fork of Arkansas River, 1,980 T/D; Area II and III, Big and Little Salt Plains, Cimarron River, 5,350 T/D; Area IV, Salt Creek tributary of Cimarron River, 400 T/D; and Area XII, Rattlesnake Creek tributary of Arkansas River, 300 T/D.

The objective of the Arkansas River project is to control the natural sources to the extent that Keystone Lake (near Tulsa, Oklahoma) would meet the Public Health Service drinking water standards for chloride of 250 mg/l or less approximately 98 percent of the time. In addition, the

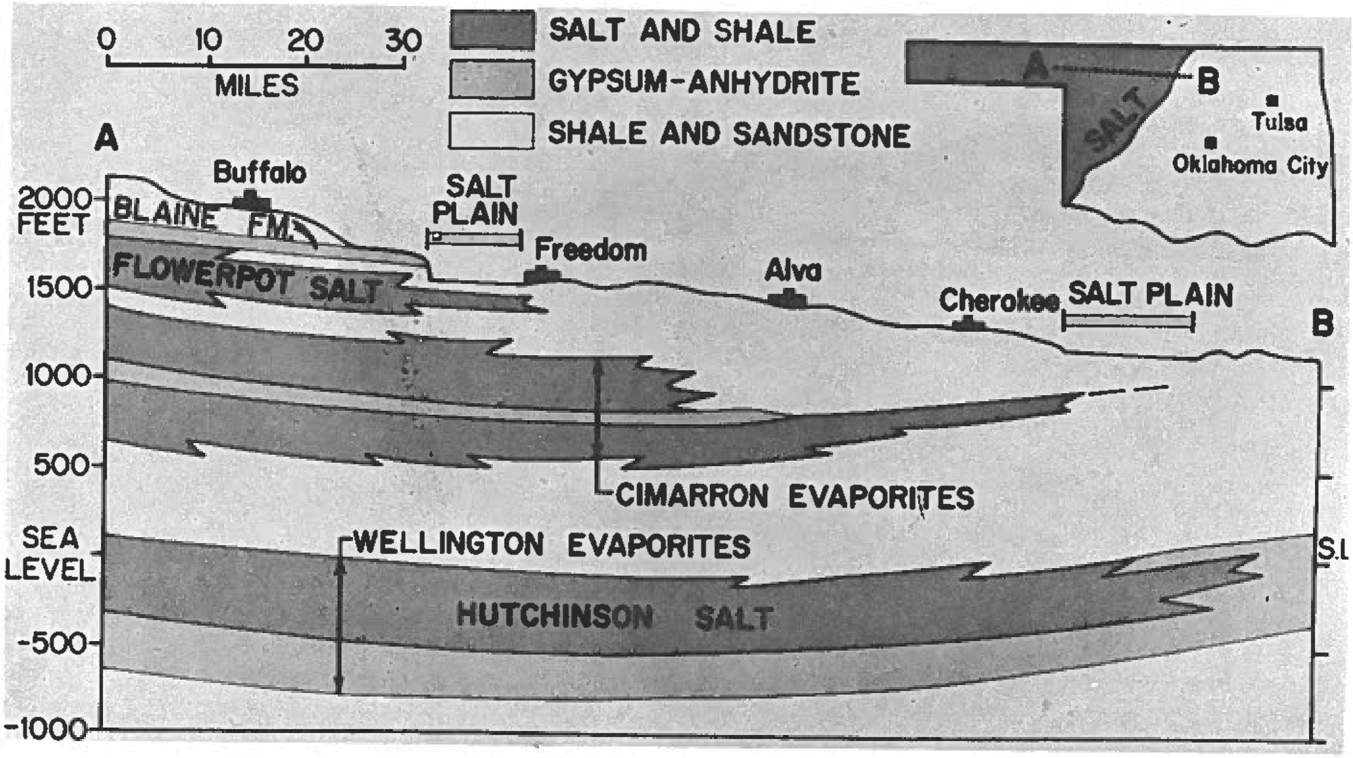


Plate 5. REGIONAL GEOLOGIC CROSS SECTION SHOWING PERMIAN EVAPORITES IN NORTHWEST OKLAHOMA

quality of water would be improved for all water users from the source areas to the mouth of the Arkansas River.

Outcropping rocks throughout this study area are Permian in age. The bedrock at many places is overlain by a veneer of Quaternary alluvium and terrace deposits. Permian rocks are mainly shale, siltstone, sandstone, gypsum, and dolomite layers that dip regionally 10 to 20 feet per mile toward the southwest and south into the Anadarko Basin. These strata are interbedded with layers of salt in the subsurface immediately below some of the salt plains, as shown on plate 5, and they also are interbedded with much salt in the subsurface to the south and southwest where the salt is still preserved in deeper parts of the Anadarko Basin. These subsurface salt deposits near the salt plains are being dissolved to form the brine that is emitted at the salt plains.

Area I is a large, low-lying, flat, salt-encrusted alluvial plain of about 30 square miles. Hence the name Great Salt Plains. About 25 percent of the natural chlorides polluting the Arkansas River comes from the Great Salt Plains. During periods of rainfall and surface runoff the salt crust on the plains is dissolved and carried into the existing Great Salt Plains Lake.

The plan of control at Area I, shown on plate 6, would be to isolate and impound the brine at the emission source and divert the fresh water around this impoundment. A dike would be constructed to divide the existing Great Salt Plains Lake and create a brine lake on the upstream side and a fresh water lake on the downstream side. The existing GSPL spillway would be used as an outlet works for the fresh water lake. Flow from the Salt Fork of the Arkansas River and its tributaries would enter the fresh water lake directly. Small dams on Spring Creek and Twin Spring Creek would have flood-control storage and would be used to regulate and divert fresh water through diversion channels to the fresh water lake. A storage and evaporation basin with pumping facilities would be used to keep the brine lake as close as possible to the present GSPL elevation over the life of the project. Chloride emissions from the Sucker Flats area north of Highway 11 would be confined within three dikes, collected into sumps, and drained by gravity through pipelines to the brine lake.

About 70 percent of the natural chlorides in the Arkansas River Basin come from source Areas II and III. The quality of water is relatively good in the upper reaches of the Cimarron River Basin; however, springs, seeps, and capillary action of highly saturated brine near the surface form salt plains at Areas II and III. At Area II the salt plain (Big Salt Plain), is a broad, flat alluvial surface encrusted with salt varying from a thin crust to about four inches in thickness.

The control plan for Area II–III, shown on plate 7, would be to store the brine at its emission source and to allow fresh water to bypass the brine areas. Brine flows from the Little Salt Plains, Area III, would be controlled by a ring dike with a positive cutoff. Controlled fresh water flows from Englewood Lake would pass in the channel around the ring dike. Downstream at the Big Salt Plains, brine flows would be retained by two dams. The concentration of brine in these pools will vary from 40,000 to 193,000 mg/l and will be saturated 85 to 90 percent of the time. Diversion of fresh water flows would be accomplished by constructing channels around the two brine lakes. These channels would have inflow from seven fresh water lakes formed by three large dams and four smaller dams. The four smaller dams would be designed to regulate fresh water flows into 28 miles of the main channel system, and would reduce the volume of brine stored in the larger Lower Brine Lake.

At Area IV, the collect-and-dispose concept is applied because of low base flow in Salt Creek. The brine flow is collected behind an inflatible dam and pumped about 4 miles

Plate 6

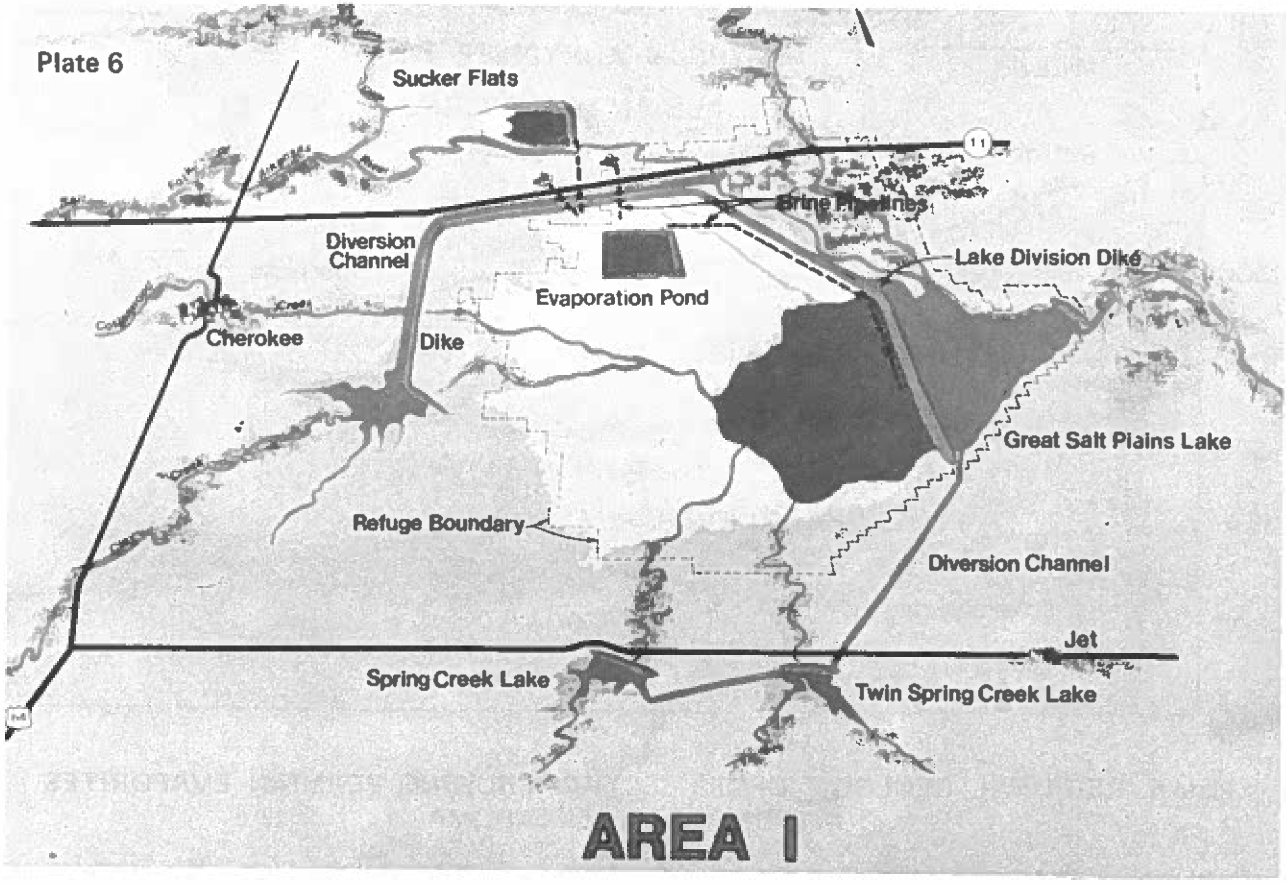
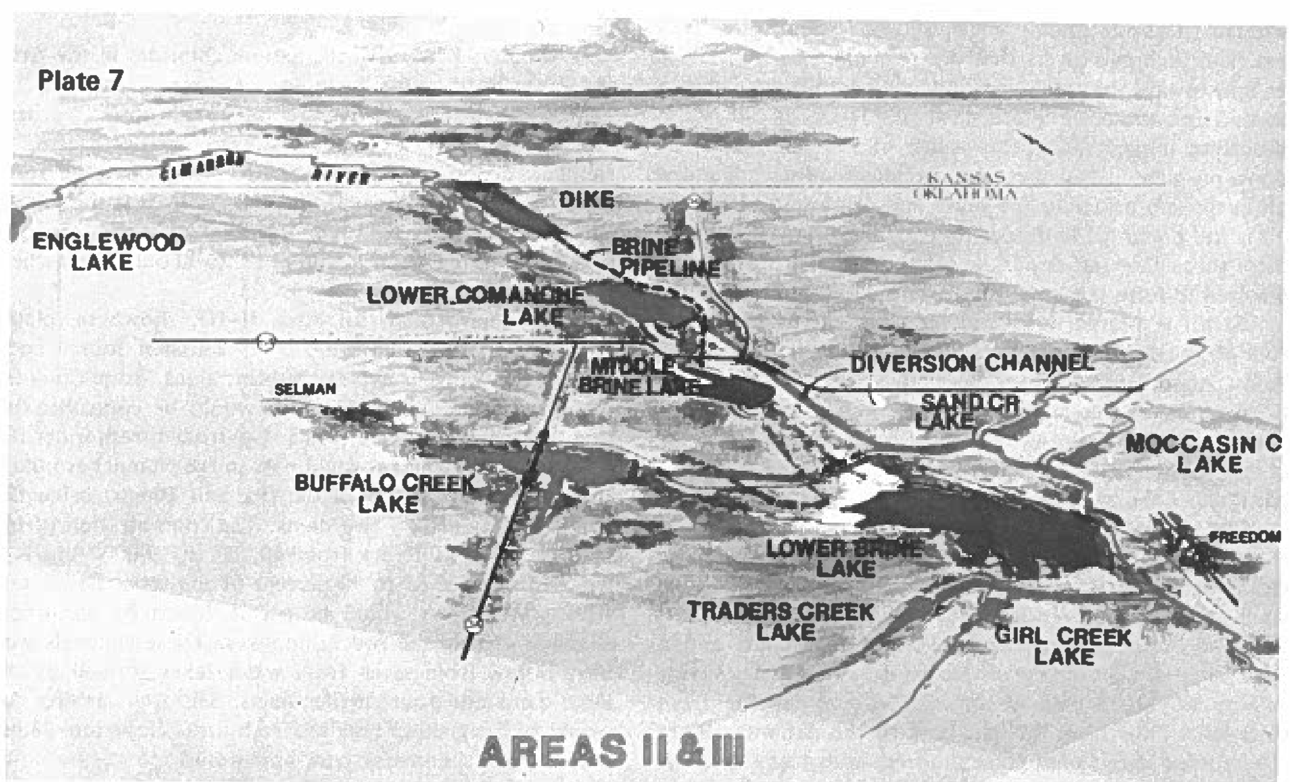


Plate 7



through a pipeline to a brine lake. High flows occur after heavy rainfall and have very low salt concentrations. This low-flow dam is designed to automatically deflate and allow these high flows to pass.

Area XII is a small contributing source spread over a large reach of Rattlesnake Creek (Kansas). An economically feasible control plan has not been developed for Area XII.

If the project is constructed for the Arkansas River, approximately 90 percent of the salt from Area I through IV would be controlled. In addition, the authorizing law requires control of manmade brines. Using Keystone Lake as a downstream reference point, we calculate that the salt load would be reduced by more than 80 percent. The actual concentration varies with time, but the percentage reduction would remain fairly constant.

The project benefits resulting from improved water quality are categorized as agricultural, municipal, and industrial water supply and others which include flood protection and limited recreation. Our initial studies, completed in June 1978, indicated an economically feasible project. However, because of the complexity and high cost of the project, we were directed to conduct additional, more detailed, economic studies. As a result of our expanded studies, the benefits have been reduced. Combining those lower benefits with the ever-increasing construction costs made the benefit-cost ratio fall below unity. Our job in the Corps is to evaluate a project such as this from the technical, environmental, economic, and social viewpoint and to make our recommendations. At this time, it appears that we do not have an economically feasible project.

Construction has begun on the Red River Project. The collection facility at Area VIII, located on the south Wichita River is essentially complete, and the Truscott Brine dam that will impound the brines pumped from Areas VIII and X is under construction.

EGD and AGI conclude tentative agreement on new data sheets

Professor Bernard W. Pipkin, University of California at Los Angeles, concluded last year that it was a shame that the American Geological Institute (AGI) had let the Data Sheet program lapse. Many EGD members will recall the inclusion of a removable geological data sheet appearing in every issue of *Geotimes*, back in the late Fifties and early Sixties. Most of us still have our collection of these very useful summaries of technical data and standards. Barney proposed that EGD undertake a committee effort to provide its members with engineering geological data sheets in similar format. The Management Board enthusiastically concluded that the membership would be well served by such an effort and Barney was asked to set the system in motion.

Just as we had prepared to publish the first two sheets, compiled by Editor Bob Fickies, GSA Executive Secretary John Frye saw the copywork and made the connection between our effort and an unknown (to us) revival effort at AGI. John set more wheels in motion, and EGD member Richard J. Proctor (AEG Past President, 1979) was asked to work out some sort of coordination. Dick is also AGI Secretary-Treasurer and was in the process of compiling five new engineering geologic data sheets for the new AGI series. Dick, EGD Chairman Allen Hatheway, AGI Data Sheet Committee Chairman, Richard V. Dietrich (Central Michigan University), and AGI Publications Director Tom Rafter have worked out a cooperative effort. It goes like this. EGD's Data Sheet Committee, chaired by Barney Pipkin, will continue to collect, screen, edit, and publish engineering geologic data sheets, through *Newsletter* Editor Bob Fickies. The data sheets will be in a format and style prescribed by AGI and will be available for use by AGI in its wider-distribution effort on a "select-as-it-will" basis. Coordination between Barney and Dick Dietrich will assist in non-duplication of efforts, and AGI can use as many of our data sheets as it wishes. We are, of course, presuming that our membership and the Data Sheet Committee will produce more EGD data sheets than AGI can accommodate in its series. That's a challenge to all! May we have your suggestions and submittals for EGD Data Sheets? Just Contact Barney at the Department of Geological Sciences, University of Southern California, University Park, Los Angeles, CA 90007.

AEG Holdredge Award goes to Dr. Anthony Brink of South Africa

The Association of Engineering Geologists (AEG) has announced in August that Dr. Anthony (Tony) B. A. Brink is its 1980 recipient of the Claire P. Holdredge Award. The award was made on the basis of Tony's 1979 book, *Engineering Geology of Southern Africa, Volume I*. The hard-bound volume is a splendid representation of classical geological observations, their engineering geological implications and geotechnical ramifications for the Archean rocks and their residual soils in Africa, below the 16th Parallel South. Volume II, in preparation, will carry the reader and user upward in the stratigraphic section to the Holocene. The book is especially valuable for its concise explanations of the interrelationships between shear strength parameters and consolidation characteristics of residual soil units, as influenced by petrography and geologic history. Dr. Brink's book is a must for all those who are or who are contemplating working in tropical and humid-climate conditions. For the remainder of us, the book is an exciting revelation of the cause and effect that links geology to geotechnical engineering, through engineering geology. The book sells for R (Rand) 37.50 and is available from Bulding Publications, P.O. Box 229, Silverton 0127 South Africa. It contains 319 pages, a pocket map of Southern African geology (in color), and a set of two stereo-triplets and supporting cross section. The book has a dozen other outstanding color illustrations bound into it.

CASE-IN-POINT

Rainstorm-induced Beach Washouts on a South Texas Barrier Island

Christopher C. Mathewson, Department of Geology, Texas A&M University, College Station, TX 77843

I. The Problem

Along a portion of the Padre Island National Seashore, heavy rainstorms cause large volumes of runoff to flow from behind a line of artificially constructed foredunes. As the runoff crosses the beach, it erodes a 10 to 20 m wide by 0.3 to 1 m deep washout channel. The beach area is open to vehicular traffic; as a result campers and visitors who are south of the washout channel site can be trapped by loss of exit access to the north. A topographic map of the site is shown in Figure 1.

The Questions

1. How is the geomorphology of the island altered when continuous foredunes are constructed in a naturally breached foredune ridge?
2. Why do the beach washouts occur?
3. What modifications to artificial dune construction procedures could be made to decrease the risk of beach washouts?
4. What engineering solutions are available to prevent beach washouts at this site?
5. How could active sedimentary processes in the area be used to reduce the risks of beach washouts?

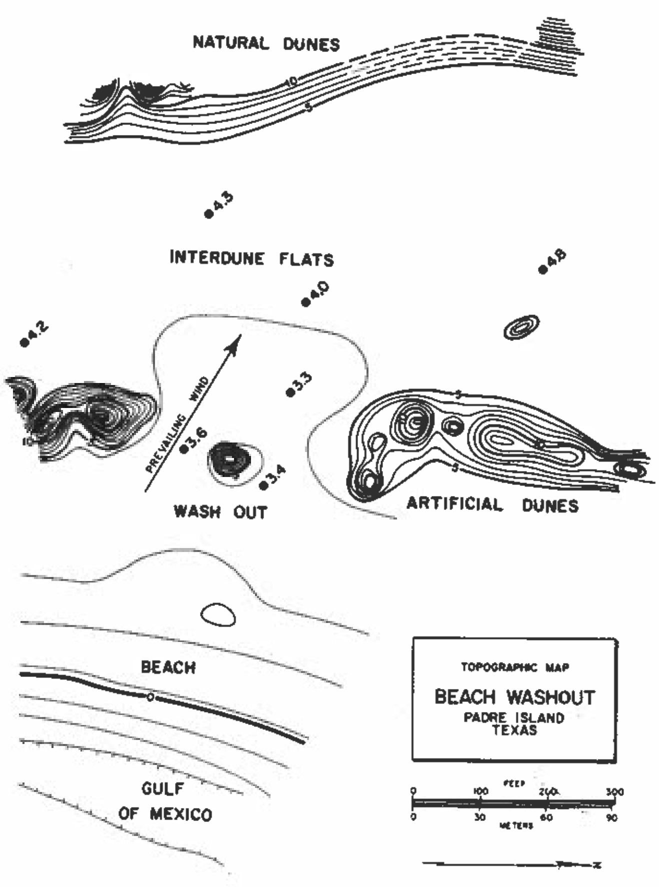


Figure 1.

Active Processes on Padre Island

Natural Processes

The primary, long-term active processes on subaerial Padre Island are aeolian, while the short-term processes are hurricanes and storms (Mathewson and others, 1975). These two processes are interdependent. Aeolian transport is inhibited when the foredune ridge and back island flats are stabilized by vegetation. However, hurricane attack of the foredune ridge strips away the stabilizing vegetation and forms a hurricane beach, allowing aeolian processes to become highly effective.

A detailed study by Mathewson and others (1975) of landward sand transport and changes in island morphology was carried out in the vicinity of Yarborough Pass, about 16 km south of the area that experiences the washout problem. Based on historical photographs and sedimentation data, this study concluded that the large, active dune fields in the Yarborough Pass area were formed through long-term aeolian processes.

The development of dune fields in the Yarborough Pass area progresses through five stages (Fig. 2). The initial morphologic features of the barrier island include the beach, the foredune ridge, and vegetated flats which grade lagoonward into wind tidal flats. Under these conditions, sediment is deposited on the beach by wave action, sorted and transported by the prevailing southeast winds, and finally, deflected northward by the foredune ridge (Fig. 2-1).

During hurricanes, storm waves attack, breach, and destroy segments of the foredune ridge (Fig. 2-2). When hurricane-induced waves form a major disruption of the ridge, this is termed a ***hurricane beach.***

The hurricane beach is topographically higher than the surrounding flats and lies above the capillary fringe of the island freshwater lens. This higher elevation allows the sand to drain; thus, revegetation is slower and aeolian processes become the major transport mechanism. Reconstruction of the foredune ridge by aeolian processes, as described by

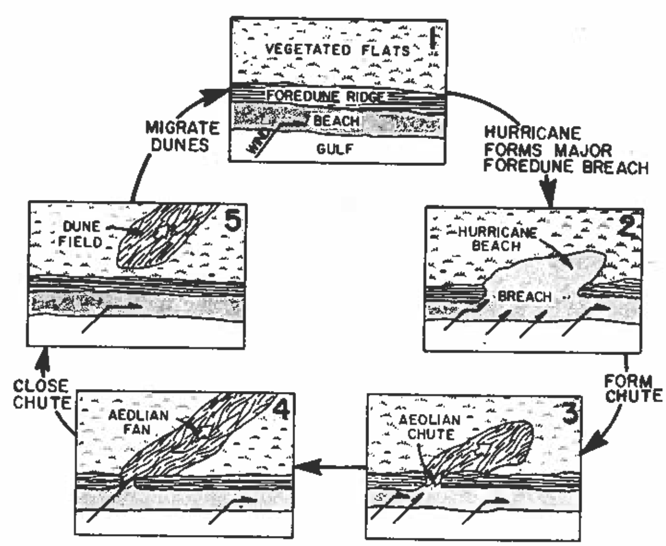


Figure 2.

Bagnold (1941) and Fisk (1959), closes the major foredune breach by forming scattered dunes which eventually coalesce, except at the southern end. Here, high sediment transport and high wind shear probably keep sand from being deposited (Fig. 2-3). An aerodynamically stable chute forms at this point which continues to feed sand through the foredune ridge, forming an aeolian fan (Fig. 2-4). Such chutes are generally aligned with the prevailing winds and have been observed to remain as transport routes for windblown sand at Yarborough Pass for more than 30 years.

Eventually, the chute becomes inefficient due to encroachment of the vegetated foredune ridge, and it closes (Fig. 2-5). Following the closing of the chute, the source of sediment for the aeolian fan is lost, and the sand migrates across the island as a dune field and becomes the back island dunes.

Foredune Ridge Reconstruction

Continuous bands of grass plantings, "16 meters wide and about 350 meters long," were placed along the foredune area at South Beach as part of the foredune reconstruction project following the destruction of the continuous foredune ridge during Hurricane Carla in 1961 (Dahl and others, 1975). The plantings were successful and a continuous foredune ridge quickly developed. Plantings were made in the springs of 1969 through 1972. By 1973–74, beach washout problems had developed. The rapid formation of the artificial foredune ridge is shown in Figure 3 where a February 1970 planting resulting in a 1-meter foredune by August.

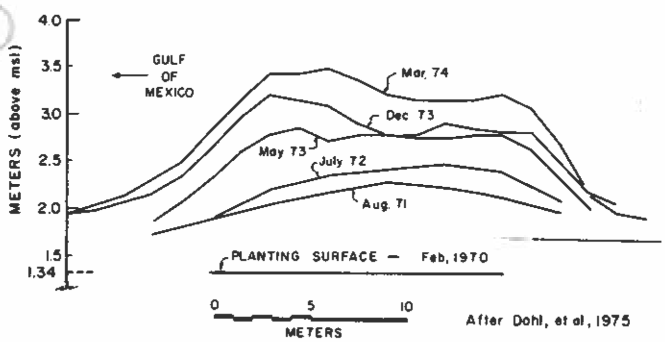


Figure 3.

II. A Solution

Dune reconstruction has altered the geomorphology of the area from a large dune field with scattered foredunes (Fig. 1-3) to a series of two, sub-parallel dune walls, separated by a deflation flat (interdune flat) (Fig. 1-4). One dune wall is the reconstructed foredune ridge, and the other is a result of aeolian transport of the former hurricane beach sands. At the south end of the foredune ridge, an aeolian chute remains—probably formed by the same processes that formed the chute at Yarborough Pass. This chute, however, is aligned with the major drainage path for surface runoff from the flat.

The beach washout develops during periods of high rainfall when the well-sorted, very fine sand is saturated, and the water table rises to the surface. Excess storm water, which cannot infiltrate the already saturated sands, collects in the area of the interdune flats forming a lake that drains gulfward through the chute. This gulfward flowing water erodes the beach and forms the beach washout.

From a comparison of the geomorphic history at Yarborough Pass and at South Beach, the beach washout is apparently artificially created and is directly related to reconstruction of the foredune as a continuous feature. Unlike the continuous and rapidly formed, reconstructed foredune, the natural foredune is discontinuous and forms slowly, allowing the low intensity drainage of any excess storm water and the formation of the aeolian fan and chute. Natural reconstruction of the foredune ridge at Yarborough Pass allowed the hurricane beach to migrate westward. This opened the northern end of the interdune flat and allowed excess storm runoff to flow across the vegetated flats into Laguna Madre rather than through the foredune and across the beach.

Foredune ridge reconstruction should be patterned after the natural processes by forming discontinuous rather than continuous foredunes. Provision should be made to allow the gradual, low intensity drainage of ponded water rather than the high intensity flows that are associated with the South Beach washout channels.

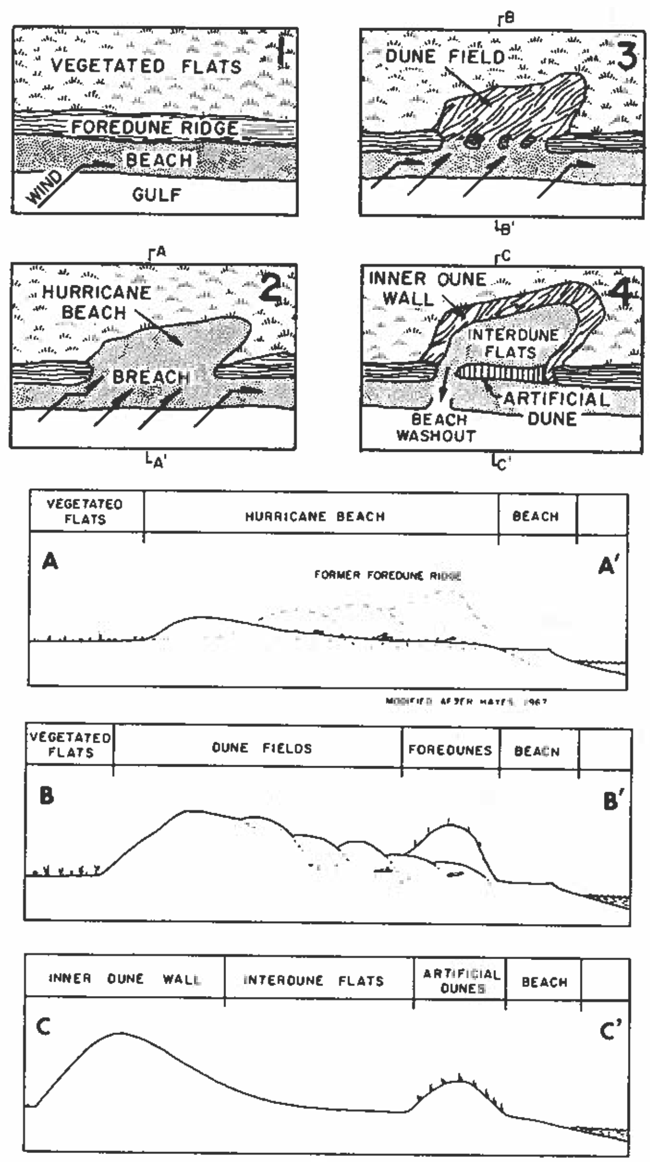


Figure 4.

Ambiguity in Evaluations of Seismic Risk

Mason L. Hill[1]

Editor's note: "Mase" Hill has had an abiding interest in faults and their behavior for well over 40 years. His 1959 paper (Bull. AAPG, v. 43) dealing with the nomenclature of faults and their separations helped to bring geologists closer together in description of such features, and many of us recall this work as influential in our early training. He has now turned his attention to assessment of fault capability and gives us the benefit of several decades of experience in dealing with faults in the economic sense of the oilfield and more recently through his involvement in seismic hazards evaluation on the West Coast.

Two groups of competent earth scientists, using identical data on faults, have drawn very different conclusions regarding potential seismic hazards. This ambiguity appears to result from a complex mix of reasons: ignorance about earthquakes, pressure to quantify seismic risk, and personal motivations. This means that both professional competence and professional ethics are involved (for example, see Ivey, 1975; Proctor, 1979). In the case of the Hosgri fault, offshore central California, some of the "experts" conclude that the nearby Diablo Canyon electrical generating facilities are in seismic jeopardy, and other "experts" think not. Whose conclusion should be accepted?

My question actually requires an answer to a more general one: How can non-earthquake generating active faults be distinguished from those that can produce significant earthquakes? For the present purpose, an "active" fault is considered to be one on which movement has occurred during Holocene time (most geologists probably agree that geomorphic evidence for displacement means that the fault is potentially active). And "significant" here means that the fault has the capability to produce an earthquake of magnitude 5 or greater.

My first point is: An active fault, regardless of its length and cumulative slip, may never have generated a significant earthquake. The displacement on any such fault may have occurred by a creep mechanism; or even if stick-slip occurred, most of the movement may have been by creep; or the cumulative displacement may have taken place by innumerable small stick-slips; or even relatively large stick-slips may have been restricted to small areas of the fault zone, at any one time. In none of the above cases would large earthquakes be produced.

My second point is: Serious consideration should be given to promoting a research effort to develop criteria for the recognition of those active faults that are not capable of generating significant earthquakes. The products of this research, by appropriate geologic, geophysical, and geodetic techniques, might provide reasonable ways to eliminate continued costly studies of a great many faults that are now considered to be potential seismic hazards. Obviously, this elimination of unnecessary work would deprive some earth scientists of substantial fees and prevent some "obstructionists" from delaying or stopping worthwhile projects. On the other hand, the public could have, for example, electrical power at more reasonable costs. Now, too often, there is a tendency to attribute potential seismic hazards to nearly all active faults, even to those that are only a few hundred of meters long and show only a few centimeters of displacement, or to surficial ones that cannot reasonably be projected to hypocentral depths. Much expensive trenching of such faults to determine the date of last movement is unnecessary. Perhaps it will be discovered by this proposed research that essentially only those faults that display geomorphic indications of substantial stick-slips, such as scarps and offset drainage lines, should be considered to be seismic threats. Then, these few could be closely monitored and evaluated for potential seismic activity. A promising start has been made in estimating the recurrence intervals and magnitudes of earthquakes produced by a few faults (Sieh, 1978). However, studies of these kinds cannot be made along all the active faults, partly because of economic and man-power limitations, in order to sort out those that will not generate significant earthquakes. Certainly, the 1:750,000 fault map of California (Jennings, 1975), which attempts to distinguish between inactive and active faults, is helpful, but it does not indicate those active faults which are not potential seismic threats.

From what I know about the manifestations of the Hosgri fault, I doubt that it is reflected in the bathymetry as are faults of known seismic potential (for example, the offshore segment of the San Andreas north of Point Arena; Curray and Nason, 1967). If the Hosgri fault is a seismic hazard, where are the ocean-bottom features similar to the scarps, sag-ponds, truncated spurs, offset drainage lines, gash fractures, troughs, pressure ridges, and so on, which are so characteristic of known earthquake-generating faults on land? I also doubt that the Hosgri fault is near enough to the central element of the San Andreas strain system (that is, the San Andreas fault) to be capable of producing a stick-slip of as much as a meter (admittedly an unjustified quantification). Furthermore, I doubt that the Hosgri fault was responsible for the 1927 Point Arguello earthquake; its epicenter is poorly known and, for the reason above, it probably is incapable of producing a 7+ magnitude event (a more likely responsible fault is an east-west trending one within the Transverse Ranges province; see Lee and others, 1980). In short, my answer to whether the Hosgri fault can generate a significant earthquake is "no," because of its characteristics and location. However, I realize there are others who think it can. Therefore, I urge research to provide criteria that can separate active faults into those that can and those that cannot cause significant earthquakes. We have too many active faults in California to "cry wolf" at the recognition of every one of them.

The ambiguity concerning seismic potential of the Hosgri fault also applies to the so-called Offshore fault near the San Onofre electrical generating facilities in southern California. Here the "experts" also come up with different conclusions about seismic risk. The situation is remarkably analogous to that at Diablo Canyon. In my opinion, this offshore fault does not have the characteristics of those faults that are known to be capable of producing significant

[1]Mason L. Hill is a consulting geologist, 14067 E. Summit Drive, Whittier, CA 90602. He is a Fellow of the Geological Society of America and an Honorary Member of the American Association of Petroleum Geologists (President, 1962), Emeritus Member of AEG, and former exploration manager of Richfield and Atlantic Richfield Companies. His publications include several on tectonics, especially on fault classifications and the San Andreas fault. This discussion is a modified version of a paper presented in a symposium on the Hosgri fault at the request of the Director of the California Conservation Department, Sacramento, California.

earthquakes. If this conclusion is a reasonable one, much of the past and future costs of the San Onofre project are patently unjustified.

Another current example of opposing opinions on seismic risk, based on a common pool of information, is at the proposed site for a liquified natural gas terminal near Point Conception, California. Here, flexural slip (see figure, Clark) in steeply dipping Miocene shale offsets unconformably overlying terrace deposits (see Clark, 1980, for an analysis of an analogous situation). Do these bedding plane "faults" extend to the hypocentral depths required for the generation of earthquakes? My answer is "no," but a contrary opinion is also held.

* * *

Why can conclusions regarding seismic risk be so divergent? Obviously, it is because we lack knowledge about the generation of earthquakes, which might provide a better basis for judgements regarding the seismic potential of specific faults. (G. K. Gilbert, in 1909, knew practically as much about the origin and prediction of earthquakes as we do now.) In addition, it appears that personal motivation, mentioned in the first paragraph of this discussion, can be a very influential factor in evaluation of seismic risk. This element is largely separate from professional knowledge and ability, but it can become the principal one in an expressed conclusion. Therefore, in situations where interpretations are highly uncertain, which are common in the practice of environmental (engineering) geology and stressed in this discussion of seismic risk, professional competence may be less critical than professional ethics. Because of this, geologists must guard against "abusing" their science for personal gain in the way lawyers legitimately "use" their discipline to defend the guilty.

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U.S. National Group is formed

Untiring efforts by David J. Varnes on behalf of the Engineering Geology Division and the Association of Engineering Geologists, over a four-year period, have come to fruition. The effort has been in support of creation of a United States National Group of the International Association of Engineering Geology. The IAEG is headquartered in Krefeld, West Germany, and has an extensive membership throughout the world. Of the major nations, only the United States has been without a recognized national group for coordinated representation.

The application for admission was presented to the Council of IAEG at the recent International Geological Congress held in Paris in July. The request was presented by Dr. Linn Hoover, Secretary of the U.S. National Committee on Geology, a body of the National Academy of Sciences. The organizing subcommittee on Engineering Geology will administer the affairs of the USNCEG and this subcommittee will meet in October or November at the annual meeting of GSA or AEG to make decisions relating to officers, procedures, mailing of the IAEG Bulletin and Newsletter, group dues and other appropriate matters. The subcommittee is made up of nine members: Charles L. Drake (ex-officio Chairman of USNCG), John B. Ivey (ex-officio President of AEG), Allen W. Hatheway (ex-officio Chairman of EGD), Richard H. Jahns (1-year term), Frank W. Wilson (1-year term), Don U. Deere (2-year term), Richard J. Proctor (2-year term), George A. Kiersch (3-year term), and David J. Varnes (3-year term). Until the USNCEG activities are established and a correspondence address is activated, IAEG will continue to handle contact with individual members. The new USNCEG should be activated in 1981.

Members of EGD are encouraged to contact David Varnes or Allen Hatheway for membership forms and the required recommendations for membership in IAEG and the USNCEG. Current yearly dues for IAEG are now set at $12 to include the very fine and valuable *Bulletin*. With establishment of the USNCEG this dues will not increase and may possibly decrease somewhat.

Bob Schuster is our activist member in geotechnical circles

Robert Lee Schuster, long-time EGD member and former Branch Chief of Engineering Geology for the U.S. Geological Survey, has accomplished four activities in 1980 of importance to the Engineering Geology Division. Judging from Bob's past activity, there may be more that we are just not aware of:

(1) Organized and convened the Atlanta Meeting (GSA) Symposium, "Geologic Hazards in Founding Offshore Structures," to be held on Wednesday 19 November at 0800. This was accomplished by way of Bob's membership on the Joint ASCE-GSA-AEG Committee on Engineering Geology. The Joint Committee has as one of its prime objectives the coordination and activation of interdiscipline meetings, symposia and papers at meetings of the three member societies;

(2) Serving as Vice Chairman (Chairman-Elect) of the 14,000 (yes, 14,000!) member Geotechnical Division of the American Society of Civil Engineers;

(3) Now the incoming Chairman of the U.S. National Committee of the International Society of Soil Mechanics and Foundation Engineering;

(4) Heavy participation in the forthcoming U.S. Geological Survey Professional Paper dealing with the 1980 eruption of Mount St. Helens. Most of the pre-eruption background work and predictions of activity was accomplished by Bob's associates at the Engineering Geology Branch of the USGS.

ATLANTA MEETING

Late developments, Joseph F. Poland Dinner

One of the several Engineering Geology Division activities at Atlanta this year will be the joint-effort Land Subsidence Symposium: State of the Art, co-sponsored by the Hydrogeology Division and convened by Tom Holzer of the Engineering Geology Branch of the U.S. Geological Survey, Menlo Park, California. The symposium is being held also to honor the long decades of guiding light represented by Joseph F. Poland of Sacramento and key USGS contributor to subsidence studies over the years. Tom Holzer's committee, including in its membership Don Helm of Lawrence Livermore Laboratory, is also staging a dinner in Joe's honor. There has been a change in dates for the dinner, which will now be held on Tuesday 18 November in Tara 5 of the Marriott Hotel, cash bar starting at 6:30 p.m. and dinner at 7:00 p.m. Tickets for the event will run about $14 and can be purchased at the Georgia World Congress Center through 5:00 p.m., Monday 17 November. For those not appearing at the meeting by this time, a personal check sent to Don Helm at Lawrence Livermore Laboratory, L-200, P.O. Box 808, Livermore, CA 94550, will secure a ticket.

Symposium on geologic hazards in founding offshore structures

Bob Schuster is to be commended for his efforts with the joint ASCE-GSA-AEG Committee in putting together this session for the Atlanta meeting. The program for the symposium will be (asterisked names are the speakers):

State-of-the-Art in Offshore Geologic Hazard Studies by *Louis E. Garrison, U.S. Geological Survey, Corpus Christi, Texas

Submarine Sediment Instability, Mississippi Delta Region by *James M. Coleman and David B. Prior, Louisiana State University, Baton Rouge, Louisiana

The Nature of Gassy Sediments Related to Geological Hazards by *William R. Bryant, Les E. Shephard, and Wayne A. Dunlap, Texas A&M University, College Station, Texas

Effects of Mudslides on Offshore Structures by *James R. Hooper, McClelland Engineers, Inc., New Orleans, Louisiana

A Case History of the Investigation for Platform Location in South Pass, Block 67, Gulf of Mexico by *James R. Faulkner and Robert E. Smith, ARCO Oil and Gas Co., Dallas, Texas

Mass-Movement Hazards on the U.S. Atlantic Continental Slope by *John C. Hathaway and James S. Booth, U.S. Geological Survey, Woods Hole, Massachusetts, and Harold W. Olsen, U.S. Geological Survey, Denver, Colorado

Recent Sedimentation History Offshore of the Mississippi Delta from Carbon 14 and Lead 210 Age Dating by *Robert J. Pottorf, Exxon Company USA, Houston, Texas

1979–1980 Geoscience News at the USNRC

Division member Gary Robbins, NRC High-Level Waste Technical Development Branch, reports that a number of important developments have occurred in 1979 and will continue through 1980 in the geoscience area. Developments include:

(1) A Commission Paper was developed assessing problems in the application of Appendix A to 10 CFT Part 100, Seismic and Geologic Siting Criteria for Nuclear Power Plants. The paper is entitled: Identification of Issues Pertaining to Seismic and Geologic Siting Regulation, Policy, and Practice for Nuclear Power Plants, SECY-79-300, April 27, 1979.

(2) On December 6, 1979, the procedural part of a regulation on high-level radioactive waste disposal was published in the *Federal Register* as a proposed rule. The proposed regulation is entitled: 10 CFR Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories. The procedural part covers administrative aspects, the licensing process, and participation by states in the licensing process.

(3) A Commission Paper on the technical criteria for high-level waste disposal has been developed. The paper is entitled: Advance Notice of Rule-Making on Technical Criteria for Regulating Geologic Disposal of High-Level Radioactive Wastes, 10 CFR Part 60, SECY-80-177, April 4, 1980. The technical criteria are in draft form and will soon be published in the *Federal Register* to obtain early comment. A proposed technical regulation is anticipated to be published this fall.

Copies of the above papers can be obtained by writing to: Secretary, U.S. Nuclear Regulatory Commission, Washington, DC 20555, or in the *Federal Register*, as appropriate. Given the importance of engineering geology in the development of geologic repositories for radioactive waste disposal, commentary by our profession on the draft technical criteria will be very valuable.

Newsletter Editor
Robert H. Fickies
Associate Scientist for
Engineering & Environmental Geology
New York State Geological Survey
Empire State Plaza
Albany, New York 12230
(518) 474-5810

PRINTED IN U.S.A.