COMMUNICATING WITH PLANNERS: MAPPING IN TEXAS

by

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Planners, though rarely trained in geology, require a wide range of geological information specially tailored to their needs. The classical geological map does not adequately convey information on landforms, groundwater, geological hazards, engineering properties of substrates, natural economic resources or biological assemblages influenced by geology. This article relates the experience of Texas geologists in developing a new kind of environmental and land resource map, and reviews the various methods used to emphasize to planners the geological base upon which they must operate.

Introduction

A common responsibility of government geologists is to transfer geological information effectively to a wide range of local and regional authorities, planners and policy makers. In Texas the main authorities concerned are state officials, councils of government (COGs), counties, and cities (Fig. 1).

Figure 1: Council of governments (COGs), bordered by heavy lines, counties (dash-dot boundaries) and principal cities of Texas. Environmental geology and land resources maps available for all COGs; special maps available for stippled COGs. Cities with capital letters have maps available now.

State agency planners include staff of the General Land Office, which oversee all state lands whether subaerial or submerged; the Railroad Commission, which regulates exploration of energy resources; the Department of Water Resources; the Department of Highways and Public Transportation; the Department of Parks and Wildlife; the Governor's Office of Budget Planning; and the Texas Energy and Natural Resources Advisory Council (TENRAC) which is principally a policy-making body. COGs are legally constituted planning authorities responsible for a group of counties through the offices of the Governor. In order to communicate effectively with all these governmental units, the geologist must be aware not only of their geographic jurisdiction but also of their legal mandate.

During the past decade the Bureau of Economic Geology, which operates as the Texas state geological survey, has

published a series of environmental and resource maps accompanied by explanatory texts and supported by numerous tables and illustrations (Fig. 2). To strengthen the impact of these maps and texts, the Bureau has followed up with workshops, colloquia, and consultations which are repeated as changes in the responsibilities of planners or personnel within the agencies occur. In maintaining communications with the planners, the geologist may have to accept not only training and consultation responsibilities outside his normal duties but even the fiscal responsibility of ensuring that the same mapping is not ordered again and again by government officials.

Historical Perspective

The past two decades have seen growing importance attached to the application of geology to environmental assessment and planning problems. Several of the original contributions came from Texas (e.g., Flawn, 1970; Brown et al., 1971). As new geological mapping of the Texas coastal zone was undertaken in the late 1960s, the concern arose that classical stratigraphical mapping, although an asset for the geological consultant community, might not reach the people with the greatest need - the planning specialists of the public policy sector. The decision was made, therefore, to develop a new type of environmental geology map which could be more readily appreciated and comprehended by educated laymen and technical people (Wermund, 1982).

Figure 2: Distribution of regions covered by environmental geology or land resources maps.

his is a complex task, especially when dealing with geological hazards which result from natural processes whose effects can be predicted in some localities, but whose frequency of occurrence is less predictable and whose exact timing is extremely difficult to gauge. On the other hand, geologists can readily recognize localities for potential flooding, shrinking and swelling soils, subsidence, landslides, volcanic eruptions, earthquakes and contemporary faulting.

Mapping the Texas Coastal Zone

One hundred and twenty-five environmental geological units were distinguished on 1:24 000 aerial photomosaics and compiled on a 1:125 000 base. Office interpretations were checked by very low-level aircraft flights and by a variety of on-site investigations.

Most of the units mapped are components of geological formations, but substrates of varying proportions of sand and mud were also identified as map units. There was no separation on the basis of formal geological age except that certain older units with greater engineering stability were distinguished.

One clearly recognized class of map units is the result of geological processes such as hurricane and stream flooding, dune blowouts, and active faults, all of which occur very rapidly and with little warning. Other "geohazards" develop at slower rates, for example, shoreline retreat and ground subsidence, natural as well as man-induced.

In low relief and nearly saturated terrains, artificial fill is common and the dredging of canals produces large spoil heaps. These and other man-made lands were mapped as special units and differentiated from natural units. Many square kilometers of the coastal zone are vegetated, and biological productivity is more important here than geological substrates. Accordingly, biological units were also recognized as a separate class of map units in environmental geological mapping.

An environmental geology master map was compiled from a biological assemblages map, a physical properties map, and an active processes map. Also developed were maps showing topography and bathymetry, current land use, man-made and water systems, rainfall and surface salinity, and mineral and energy resources. These derivative and special use maps were compiled at 1:250 000 for printing in colour. A package of maps with accompanying text for seven areas of the coastal zone was assembled into an atlas and published between 1972 and 1980 (see Fisher et al., 1972, for one example).

Mapping the Southwest Texas Basins

During the production of the coastal zone atlas, discussions with the planning office of the Governor and with planners of the natural resources agencies provoked great enthusiasm for this approach to geological mapping. The Texas Department of Water Resources had been directed to develop a state water plan, and in 1972 it commissioned the environmental geological mapping of four southwest Texas drainage basins (Fig. 2) to be modelled after the coastal atlas.

Unlike the flat coastal plain, the southwest Texas basins have considerable relief, up to 440 m locally. The region contains many projected dam sites and four major sub-surface aquifers, including the Edwards Limestone on which the city of San Antonio is dependent for its water (Fig. 3). The environmental mapping was dominated by the need to compile data for this region on the topography and recharge properties of the aquifers. Furthermore the region included a large proportion of surface mineable resources (Fig. 4).

Except for the addition of geomorphic modifiers, the environmental geologic map units were not markedly changed from those used in the coastal zone. A new series of map units

Figure 3: Outcrop of densely dissected Edwards Limestone near San Antonio. (Land Resource Unit C6 and Geological Map Unit Ke on Figure 7). These porous limestones form a prominent aquifer down dip.

were derived over the recharge and productive zones of the Edwards Limestone (Wermund and others, 1974). For the hilly, calcareous muds and sandy cuestas of the interior, moderate relief, coastal plain province another distinctive suite of map units was developed (Gustavson and Cannon, 1974).

Environmental Geologic Maps

It may be useful to compare a geologic map and an environmental geologic map with an example from the coastal zone

Figure 4: The extent of principal quarried deposits; dot-pattern = limestone for cement, solid pattern = lignite, lined pattern = uranium, G = gravel, S(Sd) = sand, C = clay.

(Fig. 5). A geologic map delineates formations which are by definition mappable units. Formations are persistent bodies of rock having easily recognizable boundaries that can be traced in the field. Formations are also first order litho-stratigraphic units consisting dominantly of a certain rock type or combination of types or possessing other unifying lithologic features. No inference of geologic age is implied.

Figure 5: A comparison of a classical geologic map (after Barnes, 1968) and an environmental geology map (Fischer and others, 1972) in Texas coastal zone immediately east of Houston.

On the geologic map (Fig. 5A) only four units are mapped. Qb and Qbb are elements of the Beaumont Formation of late Pleistocene age, Qb is a lower delta-plain facies composed of muds and very fine-grained sands; Qbb is a barrier bar facies composed principally of fine-grained sand and shells. Qal and Qbi are Recent formations. Qal is alluvium composed principally of mud with rare fine sand of a delta plain facies whereas Qbi is mostly fine sand and shell of a modern barrier island facies. Blank areas indicate water-lakes, bay or lagoon and, in the lowermost area, the Gulf of Mexico.

An environmental geology map (Fig. 5B) of the same area looks different because many more units are differentiated. However, a number of differences, for example in the exact location of geological boundaries, are due to the fact that the two kinds of mapping in this area were carried out by different geologists at different times and using substantially different aerial photographs and base maps. The newer mapping with good aerial photographs permits easier discrimination of variations in substrate and moisture content. There is also a difference in mapping philosophy; the many elements affecting man's potential use of the land are ranked for their significance on the environmental map.

A1 on the environmental map is nearly equivalent to Qbb of the geologic map, and A1 and A4 correlate with Qb. Likewise D1 and D3 of the environmental map correlate in general terms with Qal of the geologic map, and C1, C3, and C4 with Qbi.

A1 and A2 are recharge sands in the coastal aquifer. A1 is highly permeable and a nearly self-contained shallow aquifer which stands more than 1 m above surrounding units. It has the best foundation potential for local construction. A2 is a moderately permeable, fine-grained sand formed in one of the old distributaries of the Beaumont delta. It is only slightly less suitable than A1 for construction. A4 is dominantly a physical property unit composed of unstable silt and

clay, with makes for generally good cropland, but which causes construction problems from its shrink-swell soils and corrosive properties. A4 represents the intrabasin muds of the Beaumont delta plain. B4 is alluvium consisting of locally derived sands and muds deposited by immature headward eroding streams which only recently began in this area.

C1, C2, and C3 are predominantly process units related to storm surges of the Gulf of Mexico in contact with the barrier island. C1 is loose beach sand and shell, C3 is mixed sand, mud and shell of the tidal flats, and C4 is sand of fore-island dunes and vegetation-stabilized barrier flats. The wedge-shaped portion of C4 in the center of the figure represents an old hurricane washover channel. Such areas are generally subject to flooding by future hurricanes breaching the barrier.

D1 and D3 are principally vegetative units, the former being a saltwater marsh valuable as a commercial breeding ground for shrimps and fish, and D3 being a predominantly freshwater marsh. E1 represents the spoil pile of an intercoastal canal dredged parallel to the back side of the barrier island.

Unlike a geologic map which does not show differences in bodies of standing water, 12 environmental units are distinguished for the bay, lagoon, estuary, and open gulf in the Texas coastal atlas. Four of these units (F2, F3, F7, and F11) are shown in this example. F2 represents an enclosed or restricted bay, 1-3 m deep, which has generally restricted circulation or exchange, high and low extremes of salinity, a frequent deficiency of oxygen and low species diversity. F3 is open bay with depths of 2-4 m, with good circulation and exchange, only moderate salinity fluctuations, moderate to high oxygen content, and high species diversity. F7 is an abandoned beach ridge and berm commonly flooded and highly susceptible to erosion. F11 is oyster reef whose living or dead elements are not differentiated on the map. These F units are derived from compilation and sampling of biologic

data, bathymetric charts and the like. In a rich and highly productive coastal zone, their recognition is important for commercial and sports fishermen, game wardens, resort managers, park planners, and those warning and evacuating residents during hurricanes.

In 1980, after many delays due to extended, tedious cartographic production and higher costs, the final results were published. The cost of continued production of an atlas series of coloured maps, like that for the coastal zone, has more than doubled. During mapping and production new demands to map other regions of the state continued (Fig. 2). The Bureau of Economic Geology therefore sought a way to increase production of environmental geologic information in a shorter time and at a decreased cost.

Land Resources Mapping

In 1972 a need was recognized to provide a land resources map for the entire state. One example had already been made for the Houston-Galveston area council (St. Clair et al., 1975). For that work, land resource units were "mappable entities either natural or man-made that are defined by the physical, chemical, and biologic characteristics or processes which govern the type or degree of use that is consistent with both their natural quality and productive utilization".

Some 70 land resource units were distinguished during the course of statewide mapping. These were grouped into eight major categories: geohydrologic units (recharge zones of aquifers), mineral land units (containing extractable mineral or energy resources), physical or engineering property units, geomorphological or terrain units, active process units, biological assemblages, estuary-lagoon-open shelf units, and man-made land. The published map was supplemented by extensive tables giving all the characteristics and properties of these units, their stratigraphic equivalents, potential uses, areal extent by county, potential derivative units for them-

atic mapping, and the sources of the data used in the compilation (Kier et al., 1977).

An example of one kind of table used is shown in Figure 6 which evaluates the potential use of land resource units, taking into account improvements which can be made through special planning, technology and construction methods. For instance unit C9 - loose surficial sand - is suitable for foundations and construction. The scrub brush and grass which forms the cover should not be removed, septic systems should be spread out and monitored, and waste disposal sites sealed and monitored.

Comparing Land Resource and Geological Maps

A comparison of a geological map and a land resource map will yield rather similar results (Fig. 7) to those outlined earlier. The area quoted here is located over the recharge and artesian zones of the Edwards limestone aquifer and along a major down-to-the-coast fault zone. This Balcones fault system forms a dissected escarpment of 400 m relief, part of which extends to the city limits of San Antonio (Fig. 8).

Here, there are four Cretaceous formations. The oldest is the Glen Rose unit (Kgr) of alternating thin beds of resistant dolomite and limestone and readily erodable calcareous marls. The Edwards Formation (Ke) is for the most part massive to medium-bedded dolomite and limestone (Fig. 3) with very thin calcareous mud breaks. The Austin Chalk (Kau) is an important source for cement (Fig. 4). The Pecan Gap marl (and Taylor) calcareous muds are mapped as one stratigraphic unit (Kpg) in this region. Pleistocene terraces (Qt) of calcareous gravels and sands, are distinguished from younger Quaternary alluvium (Qal) also containing principally calcareous sand and gravel. Because the Edwards Formation also bears significant cherty zones, some siliceous gravels occur in greater abundance in the older alluvial deposits.

LAND RESOURCE UNITS		ACTIVITIES											
		Surface disposal of untreated liquid wastes	Liquid-waste disposal	Shallow subsurface disposal of untreated liquid wastes	Solid-waste disposal	Maintenance of feed lots	Disposal of solid waste materials	Shoreline construction	Construction of jetties, groins, and piers	Construction of storm barriers and seawalls	Coastal and inland construction	Coastal, inland, and offshore construction	Excavation including extraction of natural materials
C-1	Expansive clay mud												
C-2	Expansive clay mud and hard limestone (undiff.)	0	0								0	0	0
C-3	Limy mud										0		
C-4	Hard limestone and limy mud (undiff.)	0	0								0		
C-5	Sand and mud (undiff.)	0	0		0						0	0	0
C-6	Hard sandstone, mud, and mudstone (undiff.)	0	0	0	0						0	0	0
C-7	Moderately hard sandstone	X	X	0	0						0	0	0
C-8	Hard sandstone and conglomerate (undiff.)	X	X	0	X						0	0	0
C-9	Loose surficial sand	X	X	X	X						0	0	0
C-10	Gypsiferous red beds with dolomite	0	0								0	0	0
C-11	Fractured, steeply dipping rock	X	X	X	X						0	0	0
C-12	Hard crystalline rock	X	X		X						0	0	0

Figure 6: Natural capability for certain land resources units (from Table 11, Kier and others, 1977). Blank = no significant problems, 0 = possible problems, X = significant problems, and shaded = not applicable.

Figure 7: A comparison of a classical geologic map (after Barnes, 1974) and a land resources map (Wermund and others, in preparation) immediately north of San Antonio.

Many of the contacts on the geologic map and the land resources map are nearly identical since the mapping for each was accomplished within the same decade. The aerial photography was essentially identical and no substantial difference in topographic bases affected interpretations.

A1 and A2 on the land resources map are dominantly process units. A1 is a modern flood plain where annual floods take place with moderate to high frequency; it is composed of principally carbonate sand and gravel. The A2 unit includes a series of three terraces which are infrequently flooded; the second terrace approximates a 40-year flooding surface. The A2 unit is locally mined for sand and gravel for use in concrete, and it locally forms rich chernozem-like soils which support valuable crops.

The remaining units are generally recognized as physical property units although second-order processes and economic potential are also important in their recognition. Within the Edwards Formation, four land resource units are mapped (C2, C3, C6, and C7). C2 is moderately dissected, karstic hard carbonate with scattered sinkholes, and slopes of 5-15 per cent. It is identified separately as a significant recharge area for the Edwards aquifer. However the greatest recharge occurs in C3 which is described as karstic lowland with limestone and dolomite, frequent sinkholes, moderate faulting and joint spacing, and slopes generally less than 5 per cent.

Increased dissection and steeper slopes reduce the potential for use of land resource units C6 and C7. C6 is densely dissected limestone and dolomite with slopes all exceeding 10 per cent; C7 represents moderately dissected carbonates with slopes of 5-15 per cent. D1 is moderately dissected alternating marl, limestone and dolomite, forming a stair-step topography with variable slopes of 5-15 per cent. All units are poor grazing land.

Although classified as a bedrock unit, C11 chalk has potential as an economic resource unit for cement. The black soil over this relative low relief unit varies in its ability to sustain agriculture. The gravel unit identified as G6 is a lag gravel sometimes let down on to the chalky soils. K2 consists of low rolling calcareous muds useful for agriculture after controlled fertilization. The muds commonly form expansive soils, making construction difficult. Historically they represented the major wheat and cotton belts of post-Civil War Texas.

Approaches Used Elsewhere in the U.S.

Recognition that publicly sponsored geological surveys have responsibilities to communicate their findings beyond the technical and professional literature has of course not been unique to Texas. Other State geological surveys have histori-

Figure 8: View looking north on the terrace surface A2 of the land the resources map and Qt of the geologic map, to the fault-controlled Balcones escarpment.

cally published for nonprofessionals, and they responded strongly to the environmental movement of the 1960s and 1970s. Many originated environmental geology programs oriented toward land use planning, and a few examples may be mentioned briefly.

Alabama has developed folios of maps which are especially relevant to planning karst terranes. California has emphasized risks in landslide terranes and centers of high seismicity. Colorado developed thematic maps to plan around snow avalanches, coal mine subsidence, swelling soils, flooding, and the state made early suggestions for the multiple use of mineral lands. Illinois published a series of notes in which lakeshore and wastewater planning were strongly accentuated. West Virginia has stressed geological controls of solid landfills, and all states have emphasized mapping as the basis for these analyses.

The U.S. Geological Survey has also contributed significant research to translating geology for planners. Their biggest experiment was in the San Francisco Bay region (Kockelman, 1976 and Waananen, 1977), but they have also studied the environments of Denver, Phoenix, and Washington. Much of this work has been reviewed by Robinson and Spieker (1978) in a superior summary of earth-science maps for planners in different climates and terrains.

Communicating with the Planners

Compiling and publishing land use and environmental geology maps is an essential exercise. To some extent its success can be judged by *publication sales*, which has sometimes exceeded 2-3 000 for maps near major urban centers. Most of these sales have been to professional geologist and engineers, consultant firms and interested citizens.

Publications are not the only or even necessarily the most important means of transferring essential geological concepts and data to the planners (Wermund, 1980, 1982). *Lectures and professional conferences* are used but by themselves do not reach the key authorities, and have had little effect on public policy in Texas. *Seconding geological personnel* to regulatory and other agencies without their own specialists can be very useful, although this mechanism has not been used much in Texas.

The Bureau of Economic Geology in its *interagency committee work* regularly promotes the mapping of environmental geology and land resources. The Director is a voting member of the principal policy organization for the state, TENRAC. Other voting members include representatives of the executive and legislative branches of government as well as board chairmen and elected officials managing other state agencies for energy and natural resources. In this forum, land resources maps can provide the basis for many key decisions.

In addition, one of the Bureau Associate Directors is vice-chairman of the task force which directs the Texas Natural Resources Information System. This system maintains an up-to-date file of environmental geology and land resources maps. Results of this work have led to interagency contracts for land resources maps in critical areas, as well as financial support for printing maps originated by the Bureau. All these activities lead to direct consultation with state planners and opportunities to directly implement recommendations which result from the mapping program.

The periodic *review and consultations on planning documents* also provide excellent opportunities to communicate with planners. In several instances legislative action has required review and comment in several arenas of planning. For example, COGs are required to present their annual proposals for review prior to funding. These proposals always include a section of natural resources, and local differences in the published statewide land resources are commonly referred to in these reviews.

In Section 208 of Public Law 92500, the Federal Water Pollution Control Act and its Amendments, determine the planning requirements for controlling point-source and non-point-source pollution. In Texas, the principal elements and units of a "208 planning area" were initially derived from land resources map of the Coastal Bend COG. That derivative map became the model for all other Texas planning required by law.

In the past two years, requirements of the Surface Mining Act have led to extensive use of environmental geologic maps of the active uranium and lignite areas of Texas (Fig. 3). The plan of every surface mining venture must be offered to the state for review and approval, and the environmental geologic maps are especially valuable where assessing reclamation planning.

While the above three examples address special environmental concerns, the Environmental Policy Act has the most comprehensive effects on the review of public planning. Major federal and state actions require an environmental assessment or environmental impact statement prior to the lease or purchase of land for exploitation or construction. All such statements are reviewed by natural resource agencies of the state, members of TENRAC. Maps of land resources and environmental geology have been an integral element in these reviews. It is not unusual at these reviews to find that planners have not properly taken into account recharge areas, flood-prone localities, expansive soils, critical biologic assemblages or other problem areas.

The location of the Bureau in the state capital makes such reviews and personal consultation the best transfer mechanism with state planners, but *workshops* have been the best way for communicating with planners for COGs, counties, and cities. Since 1972, the Bureau has participated in more than 25 workshops, some repeated at the same location. In several COGs as many as three workshops have been presented in response to new problems and changes of personnel.

For most governments two different groups need attention. Elected officials need briefing in order to be attuned to planning efforts. County judges, who are among the most powerful policy makers in rural Texas, may be placed in this group. A staff group needs a workshop to learn the hands-on use of maps and how to derive from them thematic maps of hazards, waste-management, construction and other problems. Workshops require both organization and understanding of the capabilities of participants. Some come to a workshop with little understanding of maps whereas others have strong technical backgrounds.

One of the most powerful ways to transfer geological information to policy makers is through *legislative testimony*. With the appearance of land resource and environmental geology maps the Bureau has been increasingly requested to testify before legislative committees on such matters as mineral resource use, pipelines, coastal resources, solid-waste disposal and water resources. Laws on these and related topics in many cases now mention land resource and environmental maps as an element in the review process, and certain land units have been recognized as needing preservation or maintenance through legislation.

Conclusions

Texas geologists have developed a series of environmental geology and land resources maps which have contributed strongly to the governmental planning process. There is, however, no single prescription to ensure their implementation and use by planners. The best transfer mechanisms have proved to be legislative testimony, workshops specially designed for elected officials and their staff, interagency committee work, and participation by geologists in reviews and consultations on planning documents.

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