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Beyond Outcrops and Cores—Bridging the Gulf Between Geologists and Civil Engineers in Austin, Texas

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"And beside all this, between us and you there is a great gulf fixed: so that they which would pass from hence to you cannot; neither can they pass to us, that would come from thence." Luke 16:26, King James Version

The Great Gulf

Geologists and civil engineers share many common interests and concerns; both disciplines attend to the Earth, albeit from different perspectives. Geotechnical engineers, in particular, focus on the ability of Earth materials to provide stable substrates for man-made structures. Geologists, in contrast, are students of the whole Earth, and their interests span the entire gamut of materials, landforms, and processes—in both academic and applied contexts. Practical matters of ground stability involve such geologic issues as the kind of bedrock beneath a site, including its degree of induration or friability, its texture and fabric, its structural attitude, its porosity and permeability, its weathering attributes; and its typical expression on the landscape. In addition, the type, thickness, and areal distribution of surface materials are of keen interest to geotechnical engineers. Clearly, matters pertaining to both bedrock and surface deposits lie within the domain of geologic research and practice.

Yet, despite overlapping interests, it is as if a chasm (a "great gulf") separates the two disciplines. Much of the gulf stems from miscommunication and from long-term professional habits and expectations that have roots in universities, where institutional barriers commonly separate students of engineering from those in the "arts and sciences." Geologists contribute significantly to communication problems with a copious technical vocabulary that is off-putting to engineers (and to most other non-geologists as well). Besides arcane geologic terminology, some simple words are simply defined differently by geologists and engineers (for example, "soil"). In addition, geotechnical engineers need quantitative data on substrate materials and, in most instances, these demands cannot be met by normal geologic investigations. So the engineer goes his or her own way with testing and analyses. On the other hand, most geologists are only vaguely aware of civil engineering practice, and only a small subset of the geologic profession think that they need information generated by engineers. As a result, most workers within the two disciplines simply disregard one another.

Notwithstanding widespread disregard, the two professions produce information that is potentially of great value to the other, and the main locus of intersection of interests is in cities. The civil engineer needs information presented on geologic maps. Whereas, geologists—especially those mapping in an urban environment—benefit greatly from the three-dimensional perspective provided by geotechnical cores and logs.

In theory, a geologic map should provide key information to the geotechnical engineer. A proper geologic map displays areal limits of bedrock and surface deposits, and it should provide information on material attributes (at least rock type) as well as inferred three-dimensional geometry and structural attributes of bedrock and surface deposits. Alas, not all geologic maps provide this basic information. Problems with using geologic maps as baseline documents for engineering practice stem from several factors: the emphasis on map units as embodiments of geologic time, unwieldy stratigraphic nomenclature, constraints of scale, and failure to delineate surface deposits, to mention only four. Commonly, these problems interact. Scale affects the ability of the map to show precise limits of bedrock features and surface deposits. And the naming of rock units is intimately tied to stratigraphic position, which brings up arcane issues of "time-stratigraphic units" versus "rock units," thereby fomenting confusion among engineers and others. Obviously, some problems with geologic maps originate with the geologists doing the mapping. But more than this, a geologic map is always an approximation, limited by local geologic complexity, extent of exposed rock, access to outcrops, map scale, and time available for mapping. In short, a geologic map is a model of a part of the Earth; such a model requires ongoing refinement and correction.

On the other hand, geotechnical investigations provide information of enormous potential value to geologists, especially in providing third-dimensional views of substrates. This value is especially great in areas in which bedrock is covered by alluvium or other surface materials. Yet certain problems often prevent the use of this information for geologic purposes. First, geotechnical investigations are almost always project-specific. Because of this, there is no consistent attempt to apply the findings beyond limits of the project under consideration. Moreover, many (perhaps most) geotechnical boreholes are cored for clients in the private sector, so that the data are proprietary. In most instances, the core is discarded, and the logs are filed away. Almost always, the information remains unpublished. Even the results of investigations for public-sector projects may meet similar fates: subsurface data are collected on a project-by-project basis, and these data are subsequently filed away and often forgotten. For large projects, attempts may be made to retrieve pertinent subsurface data, but it is difficult to rebuild a data base after the fact. Maps showing the locations of boreholes may be flawed: many boring plans are plotted on base maps that fail to show existing on-ground features (not even topography in some instances). Often, these location maps are mere schematic illustrations, and many contain the notation "NTS" (not to scale). Tied to the lack of precision in plotting map locations is the failure of many geotechnical logs to indicate ground elevations of the boreholes. Clearly, logs without a precisely plotted location and without ground elevation are of scant value to a geologist.

In short, the geotechnical engineer needs the geologist's map. And the geologist needs the information generated by geotechnical drilling. Such a drilling project provides the geologist with invaluable perspectives (and sometimes actual samples) of the third dimension. Given these subsurface data, a geologist is able to correlate between boreholes. In this way, structures and other discontinuities may be mapped, and these interpretations may be of great value to the engineer. Valuable interpretations derived by one discipline from the work of the other provide possible bridges across the "great gulf" of flawed communication. It is important for each discipline to be aware of the expanded audience for their professional products (maps and interpretive logs). To explore specific ways of bridging the gulf, examples are presented from the urban environment of Austin, Texas. The focus here is on the geologic underpinnings of Austin, hence, the discussion focuses on geologic mapping of this area.

Austin, Texas—A Case Study in Surface Mapping and Subsurface Correlation

As pointed out by Flawn (1970), the geologic setting of Austin is dominated by two natural phenomena: the Balcones Fault Zone and the Colorado River. The fault zone has resulted in the abrupt juxtaposition of strata having markedly different properties. And of course, the prevailing northeast-southwest trend of the major faults provides a structural grain that is seen along the Balcones Escarpment and elsewhere in the Austin area. The Colorado River and its tributaries have eroded the landscape into hills and valleys, but these streams also have deposited diverse thicknesses of alluvium at various places on the landscape. Thus, the two key aspects of the local geologic environment illustrate the mutual dependence between local practitioners of geology and geotechnical engineering in Austin: the abrupt discontinuities in bedrock units within the fault zone place a high premium on the mapping abilities of the geologist. And uncertainties posed by the faulting, as well as the widespread cover by alluvial deposits, place a premium on subsurface information gained from borings drilled and cores extracted and analyzed during engineering investigations.

The map prepared by Garner and Young (1976) provides an excellent overview of the geologic setting of the Austin area. It clearly shows the sequence of Cretaceous bedrock units, the structural grain along this part of the Balcones Fault Zone, and the approximate areal extent of Quaternary surface deposits. This map, however, is limited by its scale (1:62,500, or roughly 1 inch to a mile) and by the uneven thickness and variable mappability of stratigraphic units. Despite these problems (which will be discussed further), copies of the Garner and Young (1976) maps are found on the walls of most geotechnical firms in Austin. It is used as a first approximation for engineers ascertaining general conditions at any given site, and it provides tentative information on substrate for project-planning purposes (before drilling and testing).

Scale limitations of the Austin geologic map are obvious. Most geologic mapping is done using the U.S. Geological Survey's 7.5-minute Quadrangle topographic series, and the geologic field work underlying the map by Garner and Young (1976) map was done on this base at a scale of 1:24,000 (see Rodda and others, 1970). This scale is appropriate for the uses intended for most area-wide geologic surveys. However, for purposes of engineering design, the 1:24,000 scale is woefully inadequate, as most engineering site plans are presented at scales of 1:600 (1 inch = 50 feet) or larger. Thus, the limitations of published geologic maps are apparent to the very same engineers posting the Austin Geology map on their walls and using it for initial project planning. But detailed geotechnical investigations afford many opportunities to refine the published map. The late Frank Bryant, noted local geotechnical engineer, maintained ongoing revisions of the Garner and Young (1976) map, based on findings from his many site investigations. Sad to say, the "great gulf" between geologists and engineers prevents a ready means of transmitting this new-found information back to the geologic community.

Besides scale, other problems with using the geologic map in an engineering context stem from the formulations and definitions of geologic map units in an area. This problem is even more difficult to rectify than that of map scale because of the historical constraints regarding map units (including the rules of stratigraphic nomenclature). For example, the stratigraphic section presented in the explanation of the Garner and Young (1976) map comprises rock units whose nomenclature dates back to investigations by pioneering Texas geologists (for example, Hill, 1899–1900). This bedrock section was codified in part because of the "reality" of composition and thickness of stratigraphic packages and partly as a result of the manner in which the rock section was initially described (commonly based on paleontology) at least 100 years ago. Thus, the local rock units consist of (from bottom to top): two thick limestone units (Glen Rose and Edwards) separated by thinner sequences of carbonate-rock units (Walnut and Comanche Peak); above these there is a relatively thin sequence of rock units that alternate between limestones and claystones and shales (Georgetown, Del Rio, Buda, and Eagle Ford), which are overlain by several hundred feet of relatively soft limestone and "chalk" (Austin), which, in turn, is capped by thick sequences of claystone (Taylor and Navarro).

These Cretaceous strata strike northeast-southwest and dip gently to the southeast, so older units occur on the west side of the Garner and Young (1976) map with progressively younger units to the east. However, the areal relations among these strata are significantly affected by faults. The general trend of the Balcones Fault Zone extends parallel to depositional strike of bedrock in the Austin area, and this creates ambiguity with formational contacts. That is, for some rock units it is difficult to discern whether a contact is faulted or is a normal stratigraphic sequence. But besides this, an apparent anomaly is seen in the middle reaches of the map. There, a complex mosaic pattern of fault displacements occurs among the relatively thin sequences comprising Georgetown, Del Rio, Buda, and Eagle Ford formations. No such mosaic pattern is mapped either higher in the section (within the Austin Group or the Taylor/Navarro) or lower (in the Edwards). Likewise, no similar pattern is noted west of the Mount Bonnell Fault. The question arises as to whether such a detailed pattern exists in other areas but is not discerned, owing to thicker sequences of similar rock types. Or perhaps the alternating sequences of clay shales and limestone strata were more prone to small-scale dislocations, thus imparting intricately broken structural patterns that do not occur elsewhere.

These hypotheses could be tested, using geotechnical borehole data along with detailed examination of aerial photos and follow-up field work. But to do this, it would be necessary to correctly correlate between cores extracted from the thicker units. That task, however, is fraught with problems because of difficulties with discerning appropriate "marker horizons" for reference in subsurface correlations. Now the Austin Chalk has been elevated to Group (or Division) status and comprises seven formations (Young, 1985). Although bedrock characteristics make up part of the defining attributes of these seven formations, changes in fossil assemblages are also important aspects of these units. Moreover, the recognition of the various units composing the Austin Group/Division depends on features expressed in outcrops. Subtle weathering attributes seen in exposed rock are not evident in cores, so that the formations composing the Austin Group/Division are generally not recognized by geotechnical engineers. Likewise, correlation of these units in cores poses challenges to geologists. Instead, local opportunities for correlation are provided by bentonite beds, but these intervals are not consistent in thickness (or in number) within even relatively small areas. In short, precise subsurface correlations depend on penetration of formation boundaries that are well expressed in cores. Thus, for extensive projects (such as tunnels or other linear infrastructure systems), part of the engineer's planning must include key borings designed to reach "target horizons" for correct correlation. Such borings will likely be deeper than others, so that additional budget must be proposed and justified.

Other geologic units besides the Austin Chalk pose similar problems with subsurface correlation on the basis of cores. Much effort is needed by both geologists and engineers in attempting to correlate recognizable intervals within the "blue clay" sections that comprise the Taylor and Navarro groups. Likewise, boundaries of the various members composing the Edwards Group pose challenges, owing to overall prevalence of dolomite throughout the local section. Moreover, within this dolomitic limestone, certain lithologies recur repeatedly. For example, grainstone sequences are not limited to the "grainstone member," a hydrostratigraphic unit mapped by the U.S. Geological Survey in the Edwards outcrop (Small and others, 1996). In addition, wackestone intervals are seen to recur repeatedly in Edwards' cores but are not readily seen in most outcrops. Compounding these problems are local effects of karstification, including extensive microkarst zones (and attendant low core recovery) as well as local large voids, some of which are filled by secondary materials—for example, flowstone or clay. For the voids especially, our knowledge often depends on the care exercised by the driller, who (it is hoped) will record the magnitude of abrupt drop of the kelly; otherwise, the only indication of a void is the missing interval of core (which can result from various causes).

Conclusions

Geologists and civil engineers perform their professional tasks using different methods and, commonly, differing views of the world. But both disciplines extract information from the Earth. And it is altogether too common that—owing to lack of communication—a "gulf" exists that prevents sharing of data between geologists and engineers. Both groups would benefit from a measure of détente. Engineers' logs derived from cores and geologists' maps would be improved if increased professional interactions were the norm. Several urban infrastructure projects are underway presently in Austin, and these offer significant opportunities for geologists and engineers to use the information generated by the other to produce a better "model" of reality in this complex urban environment. Perhaps we geologists should recruit like-minded engineers to attend our field trips. Perhaps, in turn, we geologists might be invited to view selected cores from notable local sites. By doing that, the "gulf" may be bridged—at least in part.

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