**Remote Sensing** *Continued*

The lab has received limited area coverage of Skylab imagery. This imagery is available in 5 in. by 5 in. and 70mm natural color positive transparencies. Southern Arizona, California, and Northern Mexico are included in Apollo and Gemini coverage. Both of the latter imagery-types have a 70mm positive transparency format.

Imagery can be used in the lab, and some coverage is available for circulation. Imagery indices are available and ordering information can be obtained through the Applied Remote Sensing Program.

Also available are microfilm catalogs and some microfilm of U.S. and foreign LANDSAT data. Microfilm readers are located in the University library. Viewing equipment in the lab includes a variety of stereoscopes, large light tables, and a color-combiner viewer for 70mm imagery.

The Applied Remote Sensing Laboratory publishes a newsletter several times a year, and Carolyn Sawtelle, the editor, will add your name to the mailing list upon request. Mail should be addressed to Applied Remote Sensing Laboratory, Geology Building, University of Arizona, Tucson AZ 85721; the phone number is (602) 884-1691.

An assistant is on hand in the lab to aid visitors in finding the necessary imagery and to furnish information. There is also a professional staff capable of applying remote sensing techniques to various fields of study including land-use and natural resources inventories.

Particular expertise of graduate student assistants J.S. Conn, John Stelling, and D.A. Miller include urban studies, land-use planning, plant ecology, plant geography, natural resources, and soils morphology. Dr. David A. Mouat, in charge of the lab, has a remote sensing background in geomorphology and plant ecology.

Although physically separated from the lab, the Geological Survey Branch of the Arizona Bureau of Mines is available to assist in interpreting remote sensing data as it pertains to the geology and nonrenewable resources of Arizona. Interested parties should contact John Vuich, a Bureau geologist who has considerable background using remote sensing data for engineering and economic geology studies.

A digitizer, densitometer, and zoom transfer scope are available for use in the Lab for Remote Sensing and Computer Mapping, another remote sensing laboratory on the University campus. Dr. Bill Rasmussen, a research professor in renewable natural resources, is in charge of the lab, which is located in the Bioscience East building, Room 203. For additional information concerning the use of this lab's equipment, call Dr. Rasmussen at (602) 884-3751.

# *Collapsing Soil–a Geologic Hazard*

**by Bruce J. Murphy**

One of the consequences of urban growth and development in the semi-arid Southwest is an inevitable upset in the natural balance of geologic conditions.

Among the responsibilities of the geotechnical engineer is recognizing these effects and any resultant geologic hazards before they cause economic and human loss. Therefore, a thorough understanding of these natural conditions is essential in these natural conditions is essential in order that we may judiciously incorporate corrective measures in engineering structures and adopt building codes for the best utilization of land.

Unfortunately, usually the only time people become aware of the impact of their physical environment is when a disaster occurs and they are directly affected by the consequence.

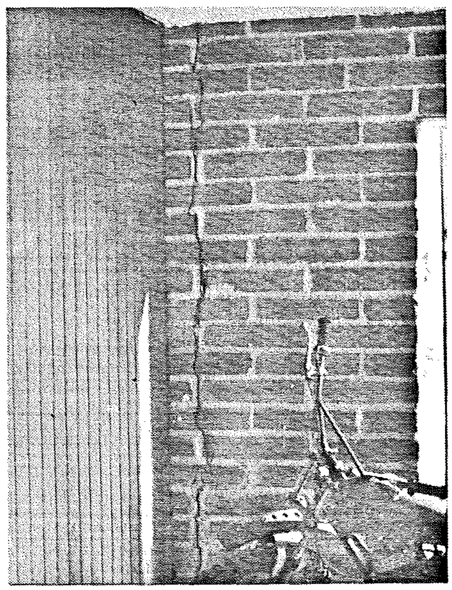
Continuing as we have in past issues of FIELDNOTES, the Geological Survey Branch of the Arizona Bureau of Mines is presenting a look at selected geologic hazards and how they affect Arizonans.

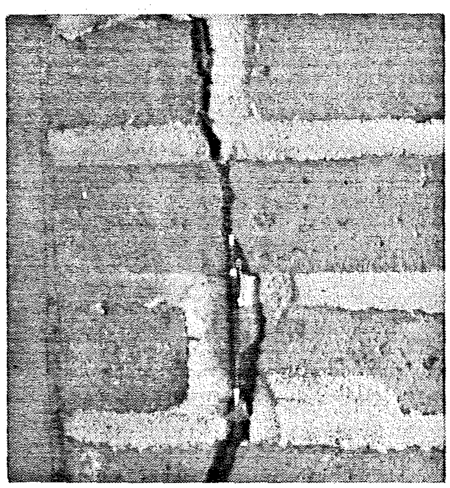
One that has affected many homeowners in southern Arizona is the problem of foundation failure resulting from collapsing soil sediments. Collapsing soil, or near-surface subsidence, can be related to two geologic processes: the failure of sediment that is subjected to rapid loss of volume upon wetting, load application, or both; and ground subsidence resulting from depression of the groundwater table due to groundwater withdrawal. The first process is generally localized, while the second may involve an entire valley. This article is primarily concerned with the problem of collapsing soils related to the first geologic process as it affects homes in the Tucson area.

Most homeowners find small, insignificant cracks in the walls and foundation of their residence due to building material and/or construction imperfections. These small cracks, while aesthetically unpleasing, are natural adjustments of the building materials to stress/strain relationships and are not normally considered serious. There are, however, many dwellings which have suffered severe settlement that has caused large cracks and separation of walls and foundations, resulting in thousands of dollars in damage. Questions often pondered by a homeowner who encounters serious structural failures in his own residence are: what is causing this particular problem?; are local officials aware of the seriousness of this phenomena?; how can it be fixed?; what could have been done in the original construction of the building to prevent this problem?

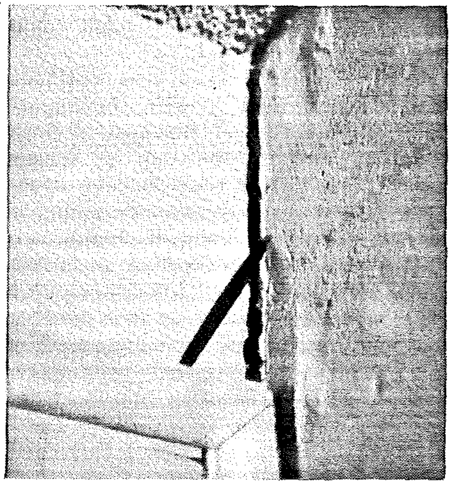
During the past 15 years, much research has been devoted to the mechanism and origin of collapsing soils, yet little of this valuable information has been applied to our own semi-arid environment. Though the exact reason for a soil to collapse is still poorly understood, most experts agree that moisture content, overburden load, and type of natural cementation (material that bonds the soil grains together) are chief factors causing instability.

When water percolates through a sediment that has been undersaturated or devoid of liquid since its formation, the supporting material in the voids between





These photos of a house's brick wall show tensional cracks with up to 1-inch displacement.



Top: vertical and lateral displacement is caused by settlement.

Bottom: patio floor was extensively damaged by differential cracking.

the grains (usually clay) are easily weakened or dissolved. When a structural load is placed on this material (0.6 ton/sq. ft. for a normal house to 1.0-2.0 ton/sq. ft. for an industrial plant), the soil fabric must adjust to this new stress condition. The less stable soil compacts more easily and this volume loss translated vertically over many feet may result in visible cracking on the surface. This settling adjustment can be rapid, taking only a few days, or it may take several years to stabilize. The important step is to recognize the soil conditions within the area and adopt a suitable scheme to alleviate the problem.

The Tucson basin lies within the Basin and Range physiographic province which is characterized by numerous mountain ranges rising abruptly from broad, plain-like valleys. The Tucson basin is theorized to have formed during early/mid-Tertiary time (25 million years ago). During this time, massive blocks of rock moved vertically relative to one another, forming high mountainous areas and contrasting low valleys. These valleys were later filled to depths of 2,000-8,000 feet with weathered alluvial material from the uplands. During this basin-fill process, the Tucson basin was characterized by an internal drainage system. In the Pliocene Epoch (11-13 million years ago), apparently the Santa Cruz River cut northwesterly between the Tucson Mountains and the Santa Catalina Mountains. This changed the drainage system into a through-flowing system, and erosion of the basin began. The Santa Cruz drainage system, which is still actively eroding the basin today, formed broad river terraces and scoured alluvial fill along mountain fronts.

In other areas, collapsing soils have been associated with some recent erosional surfaces and river terraces, such as those found in the Tucson Basin. According to many workers, collapsing soils are geologically recent, loosely-packed (up to 40% void space), and generally undersaturated with water. Smith (1938) and Pashley (1966) have mapped the recent terrace deposits within the Tucson area and have classified them from oldest to youngest as the University, Jaynes, and Cemetery terraces. These terraces are topographically higher than the present floodplain (bottomland). (See fig. 6.) Some of these terrace sediments consist of low-density, organic-rich silts, sands, clays, and gravels. The low density is the result of small voids developed as these sediments were deposited in water-deficient environments. Soils like these are likely to experience consolidation when pressure is applied.

Consolidation tests indicate that the University terrace has been subjected to preconsolidation or prior loading whereas the younger terraces are either normally consolidated or slightly underconsolidated. Field observations indicate that the University terrace is the least prone to collapsing soil problems. On the other hand, the Cemetery terrace, and to a lesser degree the Jaynes terrace and the floodplain, are subject to the most severe settling within the Tucson area. Though the degree of foundation failure varies widely, problem-prone areas in the Tucson region are located on or near the Santa Cruz, Pantano wash, and Rillito floodplains and adjacent terraces (see photographs). Foundation settling of up to 2½ feet has been reported on some residential lots, and such major structures as the high-rise Home Federal Building have developed some settling problems requiring costly remedial measures.

For existing structures, two soil stabilization methods are generally practiced to compensate for a soil's inability to bear applied loads.

One remedial method is known as underpinning (fig. 7), an expensive and difficult operation that reinforces the foundation with a new support. Underpinning requires that the foundation be excavated and slowly raised by large hydraulic jacks. A new foundation of greater width and depth is then set under each of the existing footings.

The second method uses injection of a soil cement to fill voids and displace soil

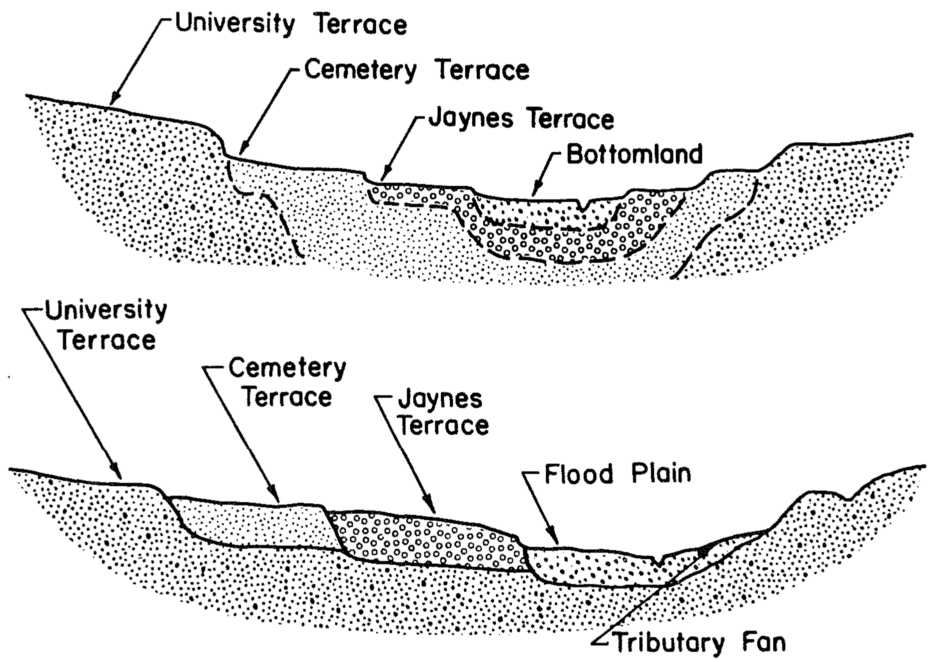



Figure 6. Conceptions of terrace relationships. The top cross-section is Smith's view (1938); the bottom is after Pashley (1966).

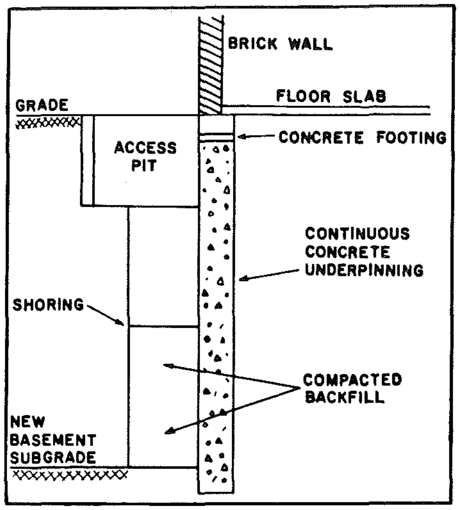



Figure 7. A cross section of the continuous underpinning method of stabilizing existing foundations.

grains (fig. 8). This method involves raising the foundation footings and injecting a low-moisture, non-plastic mixture of soil and cement down a grout pipe at specified depths. The process is repeated in several pipes until the volume of soil underneath the footings has been filled with properly-spaced balls of the soil/cement mixture. The increase in volume of the soil in the region where grouting cement is injected causes adjacent soil grains between the balls to compact. This tends to stabilize the soil along a linear zone surrounding the grout holes.

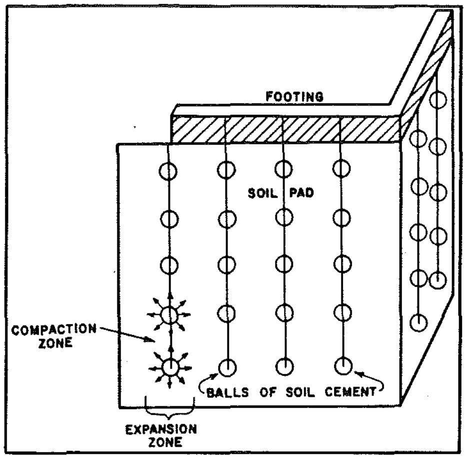



Figure 8. A demonstration of the soil-cement injection method of stabilizing damaged foundations.

Both of these methods are relatively expensive, and the resulting soil stability depends upon the skill and experience of the contractor.

Perhaps the best solution, however, lies in the fact that collapsing soil problems can be avoided by recognition of this soil condition prior to construction, and qualified testing by soil and foundation experts can determine potential foundation problems. When these conditions are found to exist the structure should be built on a preconsolidated pad with a reinforced foundation; localized soil settlement would then be greatly reduced.

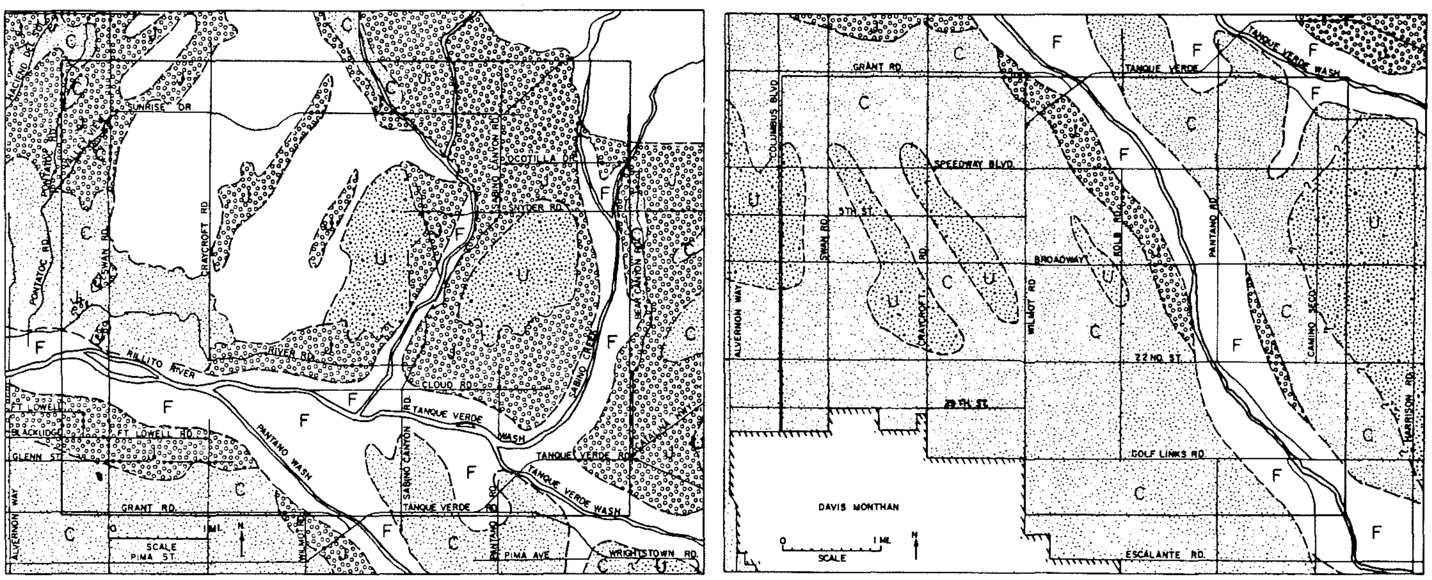
As the population of our area continues to experience rapid growth, the importance of detailed soil surveys becomes essential. The introduction of denser housing developments and heavier structures warrants a greater understanding of the soil environment and its limitations. Costs of such studies are often much less than the costs of remedial measures after damage has occurred. Also, it is possible that foundation preparation suggested by such studies might eventually represent a form of damage security approved by insurance companies.

## References

Pashley, E.F., 1966. Structure and stratigraphy of the central, northern, and eastern parts of the Tucson basin, Arizona. University of Arizona, Ph.D. thesis.

Smith, G.E.P., 1938. The physiography of Arizona valleys and the occurrence of ground water. University of Arizona Agricultural Experiment Station, Technical Bulletin 77, 91 p.

These maps are of terraces and erosion surfaces within the Tucson area. The Cemetery unit appears to have the greatest potential for foundation failure.




## EXPLANATION

Contact Between Geomorphic Units

U — University Terrace and Erosion Surface

C — Cemetery Terrace and Erosion Surface

J — Jaynes Terrace and Erosion Surface

F — Flood Plain

Present Alluvial Channel