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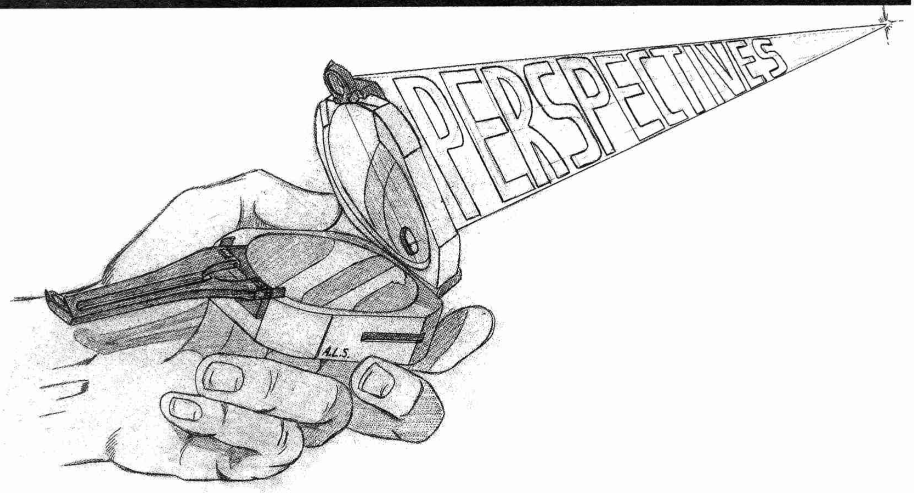

PERSPECTIVES NO. 5
WEAK ROCK
POORLY LITHIFIED COCKROACHES AND SNAKES

by Allen W. Hatheway

A column dedicated to the belief that mature engineering geologists, in addition to possessing a thorough knowledge of fundamental science, should have up-to-date perspectives on the application of their technology.

JUST like the ancient alchemists, back in 1880 folks in construction only worried about earth, fire and water. That was the year that engineering geology is believed to have come into being in the title of W. H. Penning's textbook of that name. Since then, the vocabulary of engineered construction has picked up terms like "soil mechanics," "rock mechanics," and "geotechnical engineering." With these disciplines came acceptance of soil, rock, and water as the primary materials of construction.

In the minds of most engineers, soil, rock, and water are the traditional earth materials. These terms are as friendly a connotation of earth materials as you can find. But, water aside, the terms "soil" and "rock" simply do not cover the essentials of earth materials. We need a term that strikes respect into the hearts of the knowing!

That term is **weak rock**! Every engineering geologist should come to know and respect weak rock. Treat it like a friend and you will be rewarded. This "friend" of ours is the most treacherous of all earth materials. North American engineering geologists first came into major confrontation with weak rock in construction of the Panama Canal (MacDonald, 1915), in which considerable amounts of the onerous Oligocene-aged Cucaracha ("cockroach") and Culebra ("snake") Formations were encountered in the larger cuts. MacDonald (1915, p. 55) referred to these materials as "weak rocks" and gave us the name that we prefer today, and which we rediscovered in the 1960s.

All weak-rock properties are marginal and general characteristics of weak rock are unfavorable to any sort of engineered construction (Table 1). Weak rock represents a significant percentage of exposed rock material on the earth's crust. Weak rock makes up perhaps 80 percent (my estimate) of all Cenozoic rock. It never has worthy engineering properties or behavior. Weak rock is simply never to be trusted.

TABLE 1

COMPARISON OF TYPICAL CHARACTERISTICS OF EARTH MATERIALS

Characteristic	Soil	Weak Rock	Rock
Density	L-M	M	M-H
Compressibility	L-H	M	L
Standard Pen. Test (N/15 cm)	50	50-250	250
Compressive Strength (C_o)	L(<1 MPa)	L-M(1-10 MPa)	M-H(>10 MPa)
Shear Strength (S_o)	L	L-M	M-H
Deformation Modulus	M-H	M-H	L-M
Bearing Capacity	L-M	L-M	M-H
Elastic Rebound Potential	L-M	M-H	N/A
Slake Potential	N/A	L-H	N/A
Swell Potential	0-H	L-H	N/A

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How can this undependable material be a "friend?" Simply because it is the single most important of all earth materials and it is that with which we engineering geologists are the most competent to deal. This where you can shine or where you can "bite the dust," depending on your understanding of weak rock. Dealing with weak rock represents the moment of truth.

Weak rock made the scene again in 1938, with the semi-catastrophic construction failure of the Fort Peck (Montana) dam spillway, built of expansive claystone. With this ugly memory still fresh, the Corps of Engineers began an early post-World War II (1948) study; "Shale and Weak Rocks Investigation," completed six years later (Corps of Engineers, 1954).

Europeans picked up the term in 1979 with the Seventh European Conference on Soil Mechanics and Foundation Engineering, in which Theme 2 was devoted to "Design Parameters for Weak Rocks" (Meigh and Wolski, 1979). The first major geotechnical conference devoted to the subject was held in Tokyo in 1980 (Akai and others, 1981-1982), as the International Symposium on Weak Rock.

What is "weak rock?" My personal definition is: "a consolidated earth material possessing an unusual degree of bedding or foliation separation, fissility, fracturing, weathering, and/or alteration products, and a significant content of clay minerals, altogether having the appearance of a rock, yet behaving partially as a soil, and often exhibiting a potential to swell or slake, with the addition of water; some weak rocks are also subject to time-dependent release of stored tectonically-induced stress." When weak for reasons other than weathering or alteration, weak rock is generally Cretaceous or younger in age.

Some weak rock originated as a highly overconsolidated soil, and as such, has never possessed better quality in terms of any measure of rock strength. Other weak rock, such as altered or weathered crystalline varieties, may have been the hardest of rock at one time, yet have been altered (deteriorated by passage of thermal fluids at some depth below the present ground surface) or weathered (at or near the present topographic surface) to be reduced to a weak-rock condition.

I have compiled a list (Table 2) of "geologic associations" for which you can bet a hard dollar on encountering weak rock. these situations are based entirely on my own experience. Please let me know of your comments and additions.

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TABLE 2

GEOLOGIC ASSOCIATIONS OF WEAK ROCK

Age and Lithologic Associations

1. Cretaceous or younger age; insufficient time for lithification or favorable diagenesis.
2. Permian and younger marl, chalk, or other dirty (clay-rich) carbonate rock types.
3. Most rocks classified as "claystone" (preferred term) or "mudstone" (non-preferred term; Underwood, 1967; mudrocks of the Commonwealth countries). Those rocks which have lithified only as a result of consolidation ("compaction" of classical geology) and which have little or no cementation (Mead, 1937)
4. Rock classified as "flysch," the interbedded sequence of shale and sandstone of a marine turbidite origin.
5. Sedimentary rock with an organic depositional origin resulting in the presence of sulfate minerals, calcium, iron, or magnesium, now prone to swelling and mineral-bond disintegration
6. Sedimentary rock with a lack of cementing agent(s) or dissolution of, or cation-exchange-removal of, pore and void cement.
7. Clay-rich sedimentary rock having been within the near proximity (say, hundreds of meters) to a dike or sill; the result is thermally-induced alteration short of low-grade metamorphism. The damage is probably greater if the host rock was wet and poorly lithified at the time of the intrusion. This situation is doubly-difficult to anticipate or to detect in site exploration.
8. Rocks of greenish colors, denoting the presence of chlorite as an undesirable mineral or precursor to swelling clay minerals
9. High clay or silt content; when unmetamorphosed, these are the "shaly" rocks, which are also thinly-bedded and subject to considerable rock-mass strength-reducing jointing.
10. Volcaniclastic rock in general. Unfavorable combination of clay, as primary minerals or as products of alteration, along with pyroclastic glass shards, or their alteration products, and ferro-magnesian minerals subject to degradation on oxidation.
11. Tropical marine limestone; generally within 20 degrees of the Equator.

Structural-Tectonic-Geographic Associations

12. Plate margins, former subduction zones and zones of transform or transcurrent faulting; common provenance of volcaniclastic and/or alteration-degraded ultramafic rock.
13. Zones of tectonic deformation or shear; mainly physiographic boundaries of a structural nature, or plate-margin, terrestrial faults or major intraplate fault zones.
14. Volcanic and volcaniclastic rocks found in a presently-tropical climate and within the zone of weathering

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With this list at hand, you will know how to predict the occurrence of weak rock before you reach the site on Day One of the site investigation. The mere age and rock-type associations found in the stratigraphic nomenclature of all State geologic maps, and a good many national geologic maps worldwide, will point the way; secondary consideration of present and probable Pleistocene climate will assist in substantiating your assessment.

At this point the plot actually clarifies, rather than thickens. You know what weak rock is, you know how to anticipate its potential presence at a proposed site, and you know what to look for and how to test the rock when you map and sample it or when it comes out of the core barrel. This is about as close as we can get to the magic that our colleagues in civil engineering would like us to deliver.

TABLE 3

DETERIORATION SEQUENCE FOR WEAK ROCK

1. **Mechanical breakdown** by stress relief of newly excavated rock.
2. **Hydration** of any expansive clay minerals present in the rock.
3. **Dispersion** (readjustment) of the more active clay minerals.
4. **Alteration** of layer silicate minerals.
5. **Leaching** of cementing agents.
6. **Concentration of stresses** as a result of clay-mineral (crystal lattice) and bound-water (adsorption) expansion
7. **Softening** of the rock; loss of strength and durability.

Table 3 is my interpretation of the general sequence of events that make up the natural degradation of weak rock, once exposed in unprotected site grading, road cuts, or in long-term performance of some embankments.

Weak rocks, once suspected in terms of geologic associations, should be described, mapped, logged, sampled, and tested. There is no standard method of testing to detect or assess the degree of unfavorability of the characteristics of weak rock. The tests shown in Table 4 measure properties; some before and some after various forms of stresses that tend to degrade weak rock.

TABLE 4

PHYSICAL AND CHEMICAL TESTS THAT SELECTIVELY IDENTIFY OR INDICATE DEGRADATION POTENTIAL OF WEAK ROCK

Test	Use/Indication
Size gradation	Indicates presence of loose or friable material; can be used before or after other forms of physical or chemical stressing
Particle shape	Inspect after swelling or slaking occurred
Clay mineralogy	Presence of swelling minerals
Plasticity	Indication of presence and release of swelling clay minerals
Slaking	Rate and magnitude of breakdown in air or water
Ethylene glycol sorption	Qualitative test for swelling or slaking potential
Methlyene blue sorption	Qualitative test for swelling or slaking potential
Cation exchange adsorption of lime	Suggestive of presence of swelling clay minerals
Ultrasonic disaggregation	Model a variety of field environments; wetting and agents; forces breakdown
Relative compressive strength of excavation-run fragments	Indication of degree of lithification

Summary

In 1990, 75 years after introduction of the term, there is little excuse for not recognizing and appropriately dealing with weak rock as an earth material for construction. There are many varieties of weak rock and many circumstances under which engineering geologists encounter such materials. It is imperative that we all know the rules that suggest its presence and that we then make the observations, collect the necessary data and samples, and then test to verify the presence or absence of such material, and then describe the degree to which weak rock may affect our project and formulate the means to deal with its characteristics and behavior.

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References

Akai, K., Hayashi, M., and Nishimatsu, Y. (eds.), 1981-1982, Weak rock - Soft, fractured, and weathered rock: Proceedings of the International Symposium on Weak Rock, Tokyo, 1980, 3 volumes.

MacDonald, D. F., 1915, Some engineering problems of the Panama Canal in their relation to geology and topography: U.S. Bureau of Mines Bulletin 86, 88 p.

Mead, W. J., 1937, Geology of dam sites in shale and earth: Civil Engineering, v. 7, no. 6, June, p. 392.

Meigh, A.C., and Wolski, W., 1979, Design parameters for weak rocks: Proceedings 7th European Conference on Soil Mechanics and Foundation Engineering, Brighton, U.K., v. V, p. 59-79.

Penning, W. H., 1880, Engineering geology: London, Balliere, Tindall and Cox.

Underwood, L.B., 1967, Classification and identification of shales: Proceedings of the American Society of Civil Engineers., Journal of the Soil Mechanics and Foundation Division, v. 93, no. SM6, p. 97-116.

U.S. Army Corps of Engineers, 1954, Report of investigation of expansive characteristics of shale and weak rocks: Omaha, Nebr., Missouri River Division, Civil Works Investigation No. 456, 22 p.

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STATEMENT OF OWNERSHIP, MANAGEMENT AND CIRCULATION
Required by 39 U.S.C. 3685

1A. TITLE OF PUBLICATION: AEG NEWS

1B. PUBLICATION NO.: V 0 L 3 3 N 0 4

2. DATE OF FILING: 06-06-90

3. FREQUENCY OF ISSUE: Quarterly

3A. NO. OF ISSUES PUBLISHED ANNUALLY: 4

3B. ANNUAL SUBSCRIPTION PRICE: 9.00

4. COMPLETE MAILING ADDRESS OF KNOWN OFFICE OF PUBLICATION *(Street, City, County, State and ZIP Code) (Not printers)*: 1041 New Hampshire St. PO Box 368 Lawrence KS 66044

5. COMPLETE MAILING ADDRESS OF THE HEADQUARTERS OF GENERAL BUSINESS OFFICES OF THE PUBLISHER *(Not printer)*: same as above

6. FULL NAMES AND COMPLETE MAILING ADDRESS OF PUBLISHER, EDITOR, AND MANAGING EDITOR *(This item MUST NOT be blank)*

PUBLISHER *(Name and Complete Mailing Address)*: Association of Engineering Geologist 1041 New Hampshire St. Lawrence, KS 66044

EDITOR *(Name and Complete Mailing Address)*: William K. Smith, US Geological Survey, Box 25046 MS 966 Federal Center, Denver, CO 80225

MANAGING EDITOR *(Name and Complete Mailing Address)*: N/A

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