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Correlation of Chemical, Mineralogic, and Physical Characteristics of Gulf Coast Dome Salt to Deformation and Strength Properties

by

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The technical approach employed in the analyses comprised several tasks. The first task was to compile a concise and complete database of strength and deformation properties and chemical, mineralogic, and physical characteristics of Gulf Coast dome salts. The extensive RE/SPEC salt database developed through years of testing for both government-funded projects and industry-funded characterization studies provided relevant data from 13 domes and 28 specific salt units. Because the database contained confidential data from industry-funded studies, a second task was to contact industry clients to obtain permission for using the confidential data in the study. As a result of this survey, 12 of the original 13 domes identified (27 salt units) were included in the analyses. A third task was to perform a survey of methods used by analytical laboratories and industry for measuring chemical characteristics of dome salt. Of the 20 surveys distributed, 13 were returned and revealed a variety of methods for determining chemical constituents. The fourth task was to supplement the database with additional analyses to obtain chemical, mineralogic, and physical characteristics for relevant salts if these characteristics had not been determined previously. Under this fourth task, 19 chemical, 31 mineralogic, and 32 macroscopic physical properties analyses were performed. The final task was to perform the correlation analyses making use of commercially-available software.

SUMMARY AND CONCLUSIONS

The correlations were grouped into four major analyses: (1) certain strength and deformation properties versus other strength and deformation properties; (2) strength and deformation properties versus chemical constituents; (3) strength and deformation properties versus mineralogic characteristics; and (4) strength and deformation properties versus physical characteristics. Other correlations (e.g., chemical constituents versus chemical constituents, chemical constituents versus mineralogic characteristics, etc.) were determined as by-products of these four major analyses and have been reported in a comprehensive correlation coefficient matrix. The results of the correlation analyses can be summarized as follows:

1. Large, positive correlation coefficients were calculated for indirect tensile strength and unconfined compressive strength (0.74), indirect tensile strength and cohesion (0.66), and unconfined compressive strength and cohesion (0.79).

2. A negative correlation exists between cohesion and the angle of internal friction (-0.64).

3. In general, a positive correlation exists between the steady-state strain rates determined at specified temperature and stress difference conditions and the steady-state stress exponent, as expected. However, these correlations were relatively weak, particularly for the strain rates determined at lower temperatures. The correlations between the steady-state strain rates and the thermal activation energy parameters produced mixed results with some positive and some negative correlations.

4. Steady-state strain rates and the steady-state stress exponents are somewhat positively correlated with strength parameters, while the thermal activation energy parameters are somewhat negatively correlated with strength parameters.

5. *Strength and deformation properties of dome salt are relatively unaffected by chemical constituents.* Exceptions to this observation include (a) the angle of internal friction is positively correlated with potassium (0.70) and with water insolubles (0.77), (b) cohesion is negatively correlated with water insolubles (-0.77), (c) the steady-state strain rate determined at a temperature of 298K and a stress difference of 20.69 MPa is positively correlated with magnesium (0.77), and (d) the steady-state stress exponent shows strong correlations with sodium, chlorine, calcium, and sulfate as described under Item 6.

6. The steady-state stress exponent determined at a temperature of 373K shows a strong, positive correlation with both sodium and chlorine (~ 0.90) and a strong negative correlation with both calcium and sulfate (~ -0.90). This same stress exponent shows similar correlations for halite (0.92) and anhydrite (-0.92).

7. Calcium is correlated with depth (0.75); however, sulfate is only moderately correlated with depth (0.51).

8. *Subgrain size is a good indicator of strength and deformation properties for dome salt.* The correlation coefficients between subgrain size and indirect tensile strength, and subgrain size and unconfined compressive strength are -0.77 and -0.55 (based on 8 data pairs), respectively. Subgrain size is also negatively correlated with the steady-state strain rate at a temperature of 298K and a stress difference of 20.69 MPa (-0.87), the steady-state strain rate at a temperature of 473K and a stress difference of 5 MPa (-0.70), the stress exponent determined for a temperature of 298K (-0.91), and the stress exponent determined at a temperature of 373K (-0.92).

9. *The steady-state strain rate determined at a temperature of 373K and a stress difference of 5 MPa is correlated with mean grain size (0.96) and with grain aspect ratio (0.89).*

The correlation analyses performed for the study are subject to a number of constraints and limitations. These constraints and limitations include:

- Correlation coefficients define linear dependency between variables. Therefore, even if correlations are low, two properties or characteristics may be strongly related if their relationship is governed by a nonlinear dependency.

- Under ideal circumstances, strength and deformation properties for a given salt unit should be determined on the same samples analyzed for chemical, mineralogic, and physical characteristics. In reality, properties were often determined on specimens that were taken from locations near where the samples for chemical, mineralogic, and physical characteristics were recovered. The underlying assumption is that within a small volume of salt, the properties and characteristics are homogeneous. The results of replicate tests and analyses were averaged to eliminate potential inhomogeneity; however, some bias resulting from inhomogeneity may still exist.

- Although 27 salt units from 12 domes were identified, not all strength and deformation properties were available for each unit. Therefore, the correlation coefficients presented in Chapter 4.0 are often based on small numbers of data pairs (i.e., ≤ 4). These small numbers of data pairs can produce abnormally high correlations.
- Only a single steady-state deformation mechanism was considered operational over the ranges of temperature and stress difference covered in the database. This assumption may explain why some obvious strong correlations (e.g., between steady-state strain rate and the stress exponent) were not observed.