Salt in the Early '70s

Alan H. Coogan
Kent State University

ABSTRACT

The Fourth Symposium on Salt volumes contain 1 papers of scientific technological, social and economic importance. In one manner or another, they cover a broad spectrum of the science, technology and art of understanding the occurrence, significance, properties and uses of salt and related minerals.

Highlights of the Symposium volumes are papers on salt geology, especially the distribution of salt and its significance for plate tectonic theories, environmental impact of concentrated salt usage, deep-mine rock mechanics, and the use of caverns in salt to store fuel, electrical energy and wastes.

INTRODUCTION

The Fourth and international Symposium on Salt contains one of the broadest summaries of the science, technology and art of understanding the occurrence, significance, properties and uses of salt and related minerals and rocks available at this time. Included in the April, 1973 meeting at Houston, and in these two volumes, are 123 papers of global, regional, and local import on subjects of geological, engineering, mining, environmental and varied industrial concerns. William E. Dickinson, President of the Salt Institute and one of the sponsors of the Symposium, brings into focus in this volume the current uses and outlook for the future uses of salt from the standpoint of industry, and projects these trends to 1980. In addition, he discusses the effects of salt uses on the environment. An equally audacious attempt is made here to highlight aspects of the state of the art in general for the areas touched on by the contributors to the meeting and these volumes. Recognizing that probably none is qualified for the task, deference is made to Donald R. Richner, Terraneers, Ltd., who as the moving force and general chairman of the Symposium conceived the broad outlines of the program, recruited the program committee, directed its efforts and filled in the "holes" where he knew of important areas which needed to be covered. Inasmuch as he now is unable to undertake this summary, I am doing it in his place.

FOURTH SALT SYMPOSIUM TOPICS

The Symposium covered more than 15 major topics relating to salt: geology, geochemistry, and mineralogy; tectonics and structural geology including evidence bearing on plate tectonics and continental drift; nutrition and salt uses; environmental effects of salt use; mining and processing; geophysics and rock mechanics; federal and state government regulations affecting the salt mining industry; solution mining; cavity utilization and related technology; solar evaporation; salt technology desalination and by-products. In overview, the areas of noteworthy papers are summarized in eight sections: 1) geology, 2) structural geology, tectonics, and plate tectonics, 3) geochemistry and mineralogy, 4) environmental concerns, 5) mining, processing, rock mechanics, and geophysics, 6) solution mining, 7) cavity utilization and storage, 8) solar evaporation, 9) salt production and technology/desalination and by-products.

I believe the highlights of the meeting and the papers in these volumes can be summarized very briefly by saying that new concepts regarding the occurrence, properties, and significance of salt and related evaporites are evolving. There is no stagnation here. Accepted or partially accepted theories are being challenged with new discoveries and new geographical areas are being investigated and tested. There is a growing concern, in part the result of public opinion and consequent governmental regulation, for the effects of salt use on the surface environment not displayed at the previous symposia. In mining, solar

evaporation and desalination, good engineering practices and good business practices continue to provide cheaper more efficient methods of producing salt and salt by-products; equally the methods of producing an underground cavity by solution mining to the desired size and shape are well documented and refinements are being practiced. The use of these caverns in salt for other purposes than producing salt, that is, for storing oil, gas, garbage, radioactive wastes, and electrical energy is attracting the imagination and investment of many scientists and engineers in industry and the papers in the Symposium on this subject of cavity utilization are some of the most intriguing to the lay scientist reader. Finally, a continuing controversy is revealed among the theorists and practioners of rock mechanics regarding the design, construction, safety, life and best use of mined cavities deep in the earth. Let us look at some of these topics in more detail.

GEOLOGY

In the section on the general geology of salt and other evaporites the reader finds an array of reports on widespread areas of the world ranging from arctic Canada to Poland and Egypt to Thailand. It is clear that although many of the evaporitic deposits which are well known, such as those of the Michigan Basin and New York still contain surprises (Matthews and Egleson), (Treesh and Friedman), other evaporitic deposits are just beginning to be outlined in their broad perspectives (Davies; Hite) while other deposits, some known to the ancients, are being reinterpreted (Garlicki). Others are being seen in new perspectives owing to detailed work (Jacka and Baar). Certainly, there is little to easily reconcile the conclusions of Matthews and Egleson that the potash of the central part of the Michigan basin was deposited at a time when the basin and the approaches to the basin were water covered and those of Treesh and Friedman who find that the Salina rocks of New York were deposited in environments analogous to the modern sabkha tidal flats, i.e., at or above sea level. Accordingly the "deep" versus "shallow" origin of the evaporites of the Great Lakes region controversy continues. Readers may want to look at the paper by Baar on the potash of the Prairie Evaporite in Saskatchewan for interesting insights into what the details of these potash beds can tell about geological history.

STRUCTURAL GEOLOGY, TECTONICS AND PLATE TECTONICS

In the meantime, others are going ahead and using evaporitic deposits, especially salt deposits, as part of a sequence of events that logically follows the rifting of continental plates. Hence, Kinsman and Wardlaw use salts and other facies to time the opening of the rifts. Kinsman even puts a 15 my time limit on the length of a juvenile ocean's evaporitic stage, and Wardlaw using similar reasoning and comparison of South American and African tachyhydrite (calcium chloride) deposits calls for an Aptian opening of the South Atlantic ocean but "deep" water deposition of the salts. Evans also considers the timing of South Atlantic rifting and its Albian linkage to the Gulf of Mexico. In another paper, Kupfer attempts to reconstruct the Gulf of Mexico through the Mesozoic fitting into place the key evaporitic deposits and structural configurations.

Other papers in the section on structure and tectonics consider smaller scale deformation of salt deposits and will be of interest to the reader concerned with these problems. Attention should be drawn to Bloch's new hypothesis regarding the formation of petroleum related to a salt stock and a salt "mirror" in Israel.

GEOCHEMISTRY AND MINERALOGY

The ultrafine aspect of evaporites are considered here and for those whose interests run this way attention may be drawn to the papers by Kinsman and a new theory by Hite for the origin of phosphorite deposits. The papers that aroused my interest were those by Anthony and Cline on the thermomigration of liquid inclusions in salt and by Holdoway on the effects of irradiation on fluid inclusions in salt. Both are of importance to the question of storage of radioactive wastes in salt mines and Holdoway's experiments came from the Lyons, Kansas salt mine test facility run by the U.S. Atomic Energy Commission and known as Operation Salt Vault. Elsewhere in these volumes, McClain brings the scientific and engineering community up-to-date on the status of that project.

ENVIRONMENTAL CONCERNS

Six of the papers in this section recount the effects of concentrated salt influx into the biosphere and atmosphere; another relates to planning and land use (Wallwork). A dramatic story is told by Rau on the effects of the persistence of chlorides in the waters of the Tuscawaras River in Ohio as a result of industrial operations at Barberton, Ohio. Abandoned wells and poor ground water and river water quality for 125 miles of stream documented here, resulted recently in governmental action. Others (Diment et al. and Rumer et al.) consider the effects of deicing salts used for highway clearance in the snow belt of western New York on the run-off and contamination of steams and bays. Hutchinson, in a similar way, looks at the effects of salt on vegetation along highways in Maine. Leydon states the position of part of the salt industry and what it can do to counter pollution effects of salt while deFlers and Creissels describe a successful and economic use of salt to electrolytically produce

chlorine to sterilize polluted beach waters at Hyeres, France by pumping the by-product of salt production directly to the sewage treatment plant.

MINING, PROCESSING, ROCK MECHANICS AND GEOPHYSICS

Papers in the mining section describe the incremental improvements in techniques, methods, management and processes used principally in the United States, ranging from description of the latest mining machines (Kogelmann; Fife) to plant design (Fidiam) and mine maintenance and procedures (Nicola; Bush).

To my mind, the exciting reports in this section involve the new or improved uses of radar and seismic techniques to locate boundaries between salt and mine shafts, water pockets and other non-salt features in the subsurface. A series of four papers, two by J. C. Cook and two by R. R. Unterberger address these problems. The problem of fracture identification and analysis is covered by Eaton and Myung and Helander show what down-hole tools can do to detect and investigate rock quality and deformation such as fractures, cavern detection and roof rock deformation through time.

The Symposium volume is rich in papers on rock mechanics studies of dry and solution-mined cavities, from the standpoint of theoretical, experimental, and observational studies. Dreyer describes the methods in general summary paper on determining the stability of underground caverns including their creep rates, general convergence behavior of underground systems and related surface subsidence. K. Nair and his colleagues, C. Y. Chang, R. D. Singh and A. Abdullah in a series of papers discuss the analytical methods for predicting subsidence, closure and rupture criteria for salt caverns. Serata describes the "stress control method" for stabilizing underground openings by controlling the stress envelopes through in situ measurements and differential-spacing design of support structures. His colleague, R. Chao develops parameters through computer analysis on the loss of cavity space by long-term creep interaction among multiple caverns, such as different rooms between pillars in a salt mine. Piper summarizes the results of a round-table discussion on the state-of-the-art in cavity rock mechanics. Clearly there is a considerable controversy between those who feel that sufficient approximations can now be made using sophisticated down-hole and inplace measurements in mines and those who see past mine failures and the high variability in rock formations as evidence of some wishful thinking about present capabilities. Perhaps this reflects more a state of mind than a state of art, but the consequences for safety and economic development, especially of deep dry mines, is tremendous. It would appear from Piper's summary that the facts may not be as hard as the positions.

SOLUTION MINING

A group of researchers at the University of Texas, supported by the SMRI, present a series of papers on model and laboratory experimental studies (von Schonfeldt, Ramolina, and Saberian) involving dissolved holes in salt. Haimson and Henderson separately discuss the practical aspects of fracturing for development of communication between salt wells. The general results are somewhat obvious, establishing well communication depends on the local geology, especially natural fractures, and the design of the "frac" job, i.e. well location, well completion techniques, and fracturing sequence. The case histories nonetheless are informative and Henderson gives the reader a feel for the economic costs. Special logging techniques (Hicks) and special equipment developed by Lynes packers for handling problems relating to well repair in the case of roof collapse, testing for proper fracturing, determining the condition of casing and protecting certain parts of the formation during fracturing are described. Case histories of successful solution mining developments (O'Donnell; George et. al.) round out the section.

CAVITY UTILIZATION AND STORAGE

Ever since man lived mainly in caves he has been digging holes in the ground to store supplies for later use or as garbage pits; he is still at it. In this interesting section on cavity utilization Katz outlines the general future for underground storage of gases and liquids, especially fuels, followed by Martinez's survey of the use of caverns in salt domes as nuclear power sites, and for storage of peak electric power. Following the general papers Jacoby, Corcoran et. al., Minihan and Querio, Pottier and Exteve, and Asiala consider various aspects of the storage and production of hydrocarbons from salt caverns. The papers range from case studies of the production of brine and simultaneous storage and recovery of LPG to numerical simulation and prediction of the volume and shape of storage cavities.

Lang, and Harboe (in abstract), consider the storage of off-peak base-load electrical energy by means of compressing air and storing it under high pressure in underground reservoirs and then using it as a source for power production by means of gas turbines during high demand periods. The method appears feasible not only for salt caverns but for mined caverns and porous rock formations. Both fuel and power storage and their related technologies are of special interest considering the currently acute energy crisis and the gradually increasing energy crisis that faces the world in the coming decades, a crisis which is at least partly related to distribution and storage and not supply alone.

Finally, this section contains papers by Rogers and Jacoby et. al. on storage of wastes, both inorganic and organic or mixed wastes (garbage), underground. The en-

vironmental appeal here is great, especially if one can produce a resource (brine), make a new resource (a hole-in-the-ground), save another valuable resource (surface land), and all the while make money coming and going. The safety and extremely long term potential for storage underground in salt are highlighted in the papers by McClain and by Dwyer and Thoms for the storage of hot wastes, especially radioactive wastes generated by Atomic Energy Commission plants. McClain reviews the status of the test project in a salt mine at Lyons, Kansas while Dwyer and Thoms consider models of potential movement of salt domes which are temperature dependent and note that the general trend in the behavior of domes with stored hot wastes is to "mushroom" at the top.

SOLAR EVAPORATION

New data by Baseggio on the composition of sea water concentrates shows that the compositional changes are not linear when compared to gram per liter at various evaporation stages. Jacobson and Ore use mathematical models to improve control and efficiency of solar pond modeling while Davis reminds us that solar evaporating ponds in nature do not operate simply on inorganic chemical principles. Tasch and Todd describe how to get rid of some of the undesirable bacterial products. This section contains papers on various methods of how to improve brine concentration and how to handle problems which arise from inadequate construction of solar ponds or from other factors which require additional manipulation of the system to produce product, especially those which result from leakage into or out of the pond. In two papers, Rivera and deFlers et. al. describe the problems and methods of efficient harvesting of solar salt under different climatic conditions of western Mexico and southern France.

SALT PRODUCTION AND TECHNOLOGY/DESALINATION AND BY-PRODUCTS

A great variety of engineering techniques are being tried to improve the handling of brines to extract various components in an efficient and economical way, ranging from fresh water (Awerbuch and Burbank) to other methods of desalination (Stanford, Phillips) and the disposal of the brine effluents by conversion to salable by-products by liquid-liquid extraction and other steps (Grinstead and Lingafelter). Other papers consider the behavior of trace elements during concentration by electrodialysis across ion-exchange membranes (Hiroi) a method which now has replaced the traditional salt field methods in Japan, and various variables on salt compression (Turnbull) recompression of salt evaporation (Rozyski) and aspects of crystallizer design (Canning; Bennett). It appears that if there is a way to produce salt, by-products, or fresh water economically, someone is working on it.