Course Title

Evaporites: Exploration, Development and Understanding of Hydrocarbon Associations in Evaporitic Sequences

Course Coordinator

Dr. Mahbub Hussain
Associate Professor, Earth Sciences Department

Duration

Five (5) days; 8.00am to 4.pm

Date

Open.

Course Outlines

Evaporites are responsible for trapping more than 60% of the hydrocarbon reserves in the Middle East (Edgell, 1998), yet worldwide the role of evaporites in controlling regional accumulations of oil and gas has been largely ignored. This is no longer the case. Professor Warren discusses the many reasons why hydrocarbons in carbonate and sandstone reservoirs throughout the Middle East and elsewhere are intimately tied to the style and occurrence of evaporites.

He brings some 20-plus years of experience in the applied petroleum and mineral sciences into detailed discussion of the role of evaporites as he traces and explains the evaporite-hydrocarbon association from deposition through diagenesis to halokinesis. Throughout, the emphasis is on recognising and predicting the importance of subsurface dynamics when exploring for hydrocarbon accumulations in evaporitic terrains. Participants will be shown how techniques of applied sedimentology, wireline analysis and seismic interpretation can be successfully applied to the search and production of hydrocarbons in evaporitic terrains.

This basic hydrocarbon-evaporite lecture course is four days long with an additional one-day module covering resource and metal associations.

Who Should Attend?:

Geologists, Petroleum Engineers, Well site geologists, Mudloggers, Well log interpreters, Petroleum management personnel, University faculties.

Language of Instruction

English

Location

Department of Earth Sciences, KFUPM

Registration Fee

SR 3200 per person

Course Instructors

Professor John K. Warren[1], Department of Petroleum Geosciences, University of Brunei Darussalam

Dr.Mahbub Hussain, Associate Professor, Department of Earth Scienecs, KFUPM, Dhahran.

1 - *Dr Warren is a currently a Professor in the Department of Petroleum Geoscience at the University of Brunei Darussalam (UBD). He is also an Executive Director of JK Resources Pty. Ltd. From 1993 to 1995 he was Professor of Petroleum Geology and Director of the Key Centre for Resource Exploration in the School of Applied Geology at Curtin University in Perth, Western Australia. In 1989-1992 he was Principal Research Scientist at the National Centre of Petroleum Geology and Geophysics in Adelaide and before that spent 8 years on the faculty at the University of Texas in Austin. In the early and mid seventies he worked for the Geological Survey of South Australia and Esso Minerals Australia.*

Dr Warren specializes in rock matrix characterization in evaporitic sequences. He has conducted and supervised applied and pure research in modern and ancient evaporitic sediments of Australia, Canada, Mexico, the Middle East, the North Sea, South-east Asia and the United States. He has worked as a consultant dealing with evaporite-related problems in exploration programs conducted by Asia-Pacific Potash, BHP Minerals, BHP Petroleum, Homestake, Pasminco, Shell, Chevron, Texaco, Statoil and others. He has also served as a technical expert in evaporites for the AAPG, BBC, IHRDC, and New World Horizons. In 1990 Dr Warren was appointed to the World Bank Panel of Experts and worked as a consultant to the World Bank on Maha Sarakham evaporites in Laos and Thailand. In 1986 he was appointed for six months by the Nordic Council of Ministers as the visiting professor in Nordic Petroleum Geology based at the University of Copenhagen and lecturing throughout the region on hydrocarbon/evaporite-related topics.

In 1989 he published his first book via Prentice Hall entitled "Evaporite Sedimentology; Its importance in hydrocarbon accumulations". Another more comprehensive book by him, titled "Evaporites; their evolution and economics", has just been published by Blackwell Scientific Press, Oxford UK (Oct. 1999, 448 pp.). It discusses, in detail, many aspects of evaporite studies most relevant to hydrocarbon development. As well as writing these two book, he has contributed chapters on economic aspects of evaporite

sedimentology in a number of books and has published more than 50 scientific articles in major refereed journals including: American Association of Petroleum Geologists Bulletin, APEA Journal, Australian Journal of Earth Sciences, Journal of Sedimentary Petrology, Geochimica Cosmochimica Acta, Geotimes, *PESA Journal, Sedimentary Geology and Sedimentology.*

Justification for the Course

The association of carbonates, evaporates and hydrocarbons is indisputable. In addition, recent study by a number of workers including Prof. John Warren has convincingly demonstrated evaporates as the host rock for certain base metals. A through understanding of the nature, distribution and genesis of evaporates and carbonates should help participants in better planning, exploration and management of hydrocarbons and metal resources.

Facility Requirements

- One overhead projector plus screen and spare bulbs.
- One 35 mm slide projector (carousel feed) plus screen and spare bulbs.
- Lecture room of suitable size with an ability to darken the room for 35 mm slide presentation.
- Suitable stationary for note-taking and wireline/seismic interpretation.

Anticipated Number of Participants

10 – 20.

Contact Address

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COURSE DETAIL (4 DAY LECTURE COURSE)

Topic 1: Defining the rock matrix - What is an evaporite?

Depositional and diagenetic significance of evaporites, their textures and their postdepositional evolution. The organic-mesohaline association. Primary evaporite textures and how they evolve into the shallow subsurface, during deeper burial and later uplift.

Topic 2: Brine evolution, fluid flow and hydrocarbon trapping.

Brine types and classification. Back Reactions. The potash dilemma: Marine versus nonmarine and hybrid brines Fluid and brine movement in sedimentary basins. Active phreatic regime. Compactional Regime. Thermobaric Regime. Evaporite brines as lubricants and catalysts to extensional faults or thrusts. Dissolution and brine convection. Preservation of bed contacts. Evaporites and fluid flow. Evaporites as pressure seals and hydrocarbon traps. Salt-related temperature anomalies and brine flow. Why hydrocarbons "salt out" and what this means in terms of reservoir prediction and quality.

Topic 3: Evaporite basins and their stratigraphic evolution.

Distribution of modern evaporites. Ancient evaporites. Is the present the key to the past? Building blocks of ancient evaporites; Mudflat, saltern, slope and deepwater, Evaporites - Broad scale models, Continental Evaporites, Platform Evaporites, Basinwide evaporites, The importance of hydrology. Problems in correlation. Using sequence stratigraphic principles in evaporitic terrains - when they do work and when they do not.

Topic 4: Use of wireline character in interpreting evaporite deposition and diagenesis.

Why the porosity problem goes away when evaluating evaporites. Characteristic vertical profiles of sabkha and subaqueous evaporites. Using wireline signature as an indicator of salt mineralogy and purity. Using wireline signature to recognise the effects of alteration and diagenesis in salts. The effects of salt solution on wireline character. Using wireline character as an indicator of potential reservoir quality within the underlying carbonates.

Topic 5: Sequence stratigraphy and seismic signature as a reservoir predictor.

Icehouse and greenhouse sealevels curves and their influence on marine-margin platform versus basin-wide evaporitic sequences. Do marine-based sequence stratigraphic principles work as predictors of likely reservoir positions in basinwide settings? Some examples; Messinian evaporites of the Mediterranean, sequence stratigraphy in the Zechstein. Which are more important, sealevel changes or autocyclic mechanisms when interpreting likely reservoir occurrence?

Topic 6; Formation of reservoir and trap during evaporite dissolution.

"The evaporite that was" How evaporite solution breccias and dissolution residues create excellent reservoirs. Breccia characteristics. Evaporite solution collapse breccias. Breccia geometries. Diapiric solution breccias, rauhwacke, preferential dissolution. A classification of dissolution-associated structural and diagenetic reservoirs. Other evaporite indicators: nodule and crystal replacement, silicified evaporites, calcitization and dedolomitization, Celestine and strontium as evaporite indicators. Barite and fluorite as evaporite indicators? Late diagenetic evaporite cements, burial seals and their influence of fluid flow and reservoir quality.

Topic 7: Salt Tectonics and its control on reservoir distribution.

Physics of halite and salt systems. Pressure effects. Thermal effects. Flow textures and rates. Salt tectonics; diapirism under extension, evolution of extensional diapirs, sedimentation and geometry, is diapirism driven by differential loading, deformation of salt sheets. Regional detachments and growth faults as controls on structural reservoirs. Falling diapir and turtle structure reservoirs. Raft tectonics and reservoir distribution Contractional salt tectonics: shortening associated with gravity gliding, structural reservoirs in thin-skinned fold and thrust belts and inverted basins. Sediments interact with flowing salt to control reservoir quality. Predicting reservoir position by understanding the interactions between diapir stage, style and sedimentation. Suprasalt clastic sedimentation, suprasalt carbonate marine shelf sediments, subsalt sediments.

Topic 8: The depositional-diagenetic association of evaporites with hydrocarbon generation.

Oxygen content and salinity fluctuations. Biota as a response to salinity fluctuations: Type 1 versus Type 1-2 kerogens in evaporitic settings. Intrashelf basins in saltern evolution and the importance of early burial setting in the preservation potential of oil-prone source rocks. Source maturity in halokinetic basins. Hydrocarbon carrying-capacity and the "salting out" of oil and gas in various subsurface brine chemistries. Thermal conductivity in evaporite systems and its effect on differential source maturation. Evaporites as seals and controls of reservoir geometry and producibility.

Topic 9: Evaporitic carbonates, dolomitization and reservoir enhancement.

Is a the presence or absence of a reef the most important aspect of reservoir quality and prediction in evaporitic settings. How do ramp and platform carbonates interact with platform and basinwide evaporites? How does the nature and physical properties of sedimentary dolomite change with increasing temperature and pressure? What does this mean in terms of reservoir prediction. Predicting intercrystalline porosity in a basin.

RESOURCE AND METALS MODULE (OPTIONAL ONE DAY)

Topic 1: Evaporites as a mineral resource.

Introduction, Potash Evaporites, Quaternary Potash, Qaidam Basin, Danakil Depression, Ethiopia, Inland chotts and coastal sabkhas in Algeria and Tunisia, Sylvite in the Amadeus Basin, Australia, Potash from brine wells, Ancient Potash, Rhine Graben, Khorat Plateau, Thailand, Permian Potash in Europe and North America, West Canadian Basin (Devonian), So how does potash form? What controls potash quality? Salt anomalies and potash leaching, Other significant potash deposits, Canadian Maritimes (Mississippian of Nova Scotia and New Brunswick), Trans-Atlantic potash: West Africa and Sergipe Basin, Brazil, Moroccan Meseta (Triassic), Other economic evaporite salts, Borates, Gypsum and halite (rock salt), Gypsum, Rock Salt (halite), Iodine, Bromine and Lithium, Nitrates, Magnesite and magnesia, Sodium carbonate, Sodium sulphate, Sulphur, Zeolites. A summary of the various exploration models.

Topic 2: Low temperature evaporite-metal associations.

Introduction, What does an evaporite do in the subsurface? Ore fluid chemistry ("metal carriers") Low temperature diagenetic, Sulphur redox reactions ("metal fixer"), Bacterial sulphate reduction (BSR), Thermochemical sulphate reduction (TSR), Sulphate reduction and metallogeny, Diagenetic evaporite-metal association, Syndiagenetic reduction & organic enrichment, Bedded salt and diagenetic copper, Sediment-hosted stratiform Cu deposits with an evaporite association, Bedded salt and stratiform sediment-hosted Pb-Zn deposits, Diapiric salt, diagenesis and mineralisation, Caprock-hosted Pb-Zn, Peridiapiric organic-rich pyritic shale hosts, Peridiapiric stratiform Pb-Zn, Peridiapiric Copper, Peridiapiric ferroan cements, Base metals, evaporites and diagenetic accumulations: A summary of the various exploration models.

Topic 3: High temperature evaporite-metal associations.

Magmatic Associations, SO4 evaporites: a sulphur source in Ni-Cu deposits, Hydrothermal salts, VMSD deposits in subduction-related island-arc settings, VMSD's at mid-oceanic or back-arc spreading centres: VMSD's at sediment-covered spreading centres with high sedimentation rates, VMSD's at sediment-starved spreading centres with adjacent dissolving evaporite beds contributing to brines, Red Sea deeps, Summary of Red Sea mineralisation mechanisms, Variations on the evaporite/hydrothermal theme - What is a sedex deposit? Fe-oxide rich mineral deposits: Interactions of magmatic hydrothermal and evaporite-derived waters, Evaporite-base metal interaction in the metamorphic realm, Proterozoic Cu-Au-U deposits in meta-evaporite terranes, Extraterrestial evaporites.