Evaporite Minerals of the Zechstein Sequence

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1.0 Evaporite Minerals of the Zechstein Sequence

The rocks were precipitated through evaporation from shallow partially land-locked seas in a hot arid climate. Since Zechstein cycles are derived from evaporation of sea-water the most abundant mineral is Halite, as sea-water contains mainly sodium chloride. During sea-water evaporation other minerals are deposited depending on the concentration of Calcium, Magnesium and Potassium cations along with Chloride, Sulphate and Carbonate anions in the remaining solution.

Typically Carbonates (usually calcium) precipitate first, followed by Sulphates (first Calcium, then Magnesium, possibly Aluminium). Further evaporation will start the precipitation of Chlorides; initially Sodium Chloride and later Potassium chloride.

	Carbonates	**Sulphates**	**Chlorides**
Calcium	Calcite	Anhydrite Gypsum	
Magnesium	Dolomite Magnesite	Epsomite Keiserite	Bischofite Kainite
Potassium		Langbeinite Polyhalite	Carnalite Sylvite
Sodium			Halite

2.0 Halite

Chemical formula:	NaCl
Crystallographic system:	Isometric, Cubic
Cleavage:	Perfect three direction cube
Fracture:	Conchoidal, Soft to brittle
Solubility:	Water-soluble
Hardness:	2.0-2.5
Density:	2.17
Colouration:	Colourless, white and pearlescent, yellowish, grey, pink, orange
Streak:	White
Lustre:	Vitreous
Common form:	Predominantly cubes and in massive sedimentary beds, but also granular, fibrous and compact.
PE:	4.63 barns/electron
GR:	0 API
Fluorescent:	Fluorescent

Halite may appear frosted, or milky through inclusions of water, Sylvite or Anhydrite – and is often stained pink by ferrous minerals.
White lath-like inclusions are common in massive crystalline Halite. Often these are of Anhydrite. However they may also be of Polyhalite (giving high Gamma Ray), or Epsomite (resulting in increased magnesium concentration of mud).






3.0 Potassium Salts

Nearly 7% of naturally occurring Potassium, is the radioactive isotope K41. Potassium salts therefore give high gamma-ray response.
Ocean water contains about 0,07% Potassium and it is necessary to evaporate 98% of the water to make potassium salts start to crystallize.

The main potassium salts are:

Sylvite	(KCl)
Carnallite	($KCl.MgCl_3.6H_2O$)
Langbeinite	($K_2SO_4.2MgSO_4$)
Polyhalite	($K_2SO_4.MgSO_4.2CaSO_4.2H_2O$)

These minerals are fairly common within the evaporitic rocks of the Zechstein sequences occurring in the North Sea. They are commonly mixed together, often on a microscopic scale and may occur as inclusions within crystals of other salts.
Potassic salts are commonly interlaminated with and included within massive halite deposits. All these salts may have inclusions and potassic salts can be associated with thin muddy laminae or anhydritic laminae.
On density logs these evaporites can be fairly easily separated from Halite and each other. Their separation in cuttings samples (bearing in mind their affinity for water) is less simple. The pictures included here are a rough guide as these minerals appear differently in cuttings samples and colouration can change due to associated mineralization.

3.1 Sylvite

Chemical formula:	KCl
Crystallographic system:	Cubic (octahedral crystals)
Cleavage:	Very good cube
Fracture:	Uneven, Soft to brittle
Solubility:	Water-soluble, very soluble (deliquescent)
Hardness:	2.0
Density:	1.99
Colouration:	Colourless, white and pearlescent, yellowish, grey, orange
Streak:	White
Lustre:	Vitreous greasy
Common form:	As cubes and octahedra crystals, columnar, in crusts, coarse granular, micro-crystalline matrix, fibrous
PE:	8.47 barns/electron
GR:	731 API
Fluorescent:	Non-fluorescent

Pure Sylvite is colourless, but it is commonly heavily included with a brick-red to orange substance that is probably hematite or limonite. In the Zechstein it commonly occurs admixed with Halite, the mixture looks like red granite, and is mined as the potash ore Sylvinite. Here the Sylvite is present as an opaque brick red to orange matrix around mainly Halite crystals. It is usually quite hard and crunchy, it often gets miss-described as red-brown to brick red Mudstone or Siltstone.

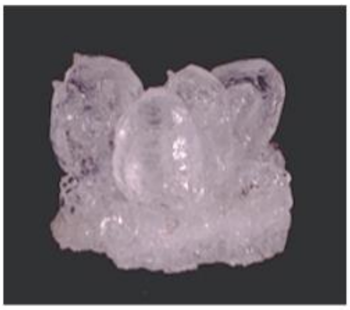





3.2 Carnallite

Chemical formula:	KMgCl3.6H2O
Crystallographic system:	Orthorhombic dipyramidal
Cleavage:	None
Fracture:	Conchoidal, brittle, fusible
Solubility:	Water-soluble
Hardness:	2.5
Density:	1.6
Colouration:	Colourless, white, greenish, yellowish, orange; in SNS primarily pink, reds, and flesh colours.
Streak:	White
Lustre:	Vitreous, greasy
Common form:	Thick-tabular crystals, pseudo-hexagonal, coarsely-granular, masses, fibrous, compact
PE:	4.07 barns/electron
GR:	208 API
Fluorescent:	Fluorescent

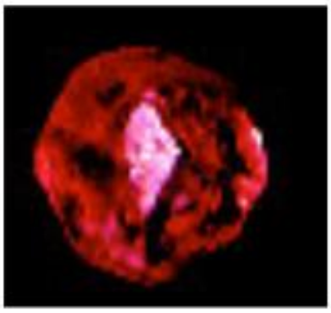
Can form distinctive elongated ‘slipper’ or ‘gondola’ shaped pink or red crystals or crystal fragments. Very Low density.

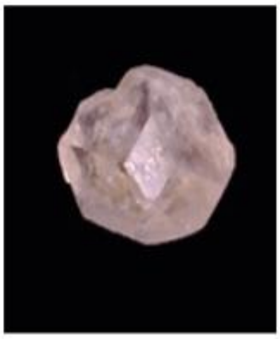





3.3 Kainite

Chemical formula:	KMg(SO4)·Cl·3H2O
Crystallographic system:	Monoclinic
Cleavage:	Good
Fracture:	Conchoidal, brittle, fusible, splintery
Solubility:	Water-soluble
Hardness:	2.5-3.0
Density:	2.15
Colouration:	Colourless, white, Blue, Violet
Streak:	White
Lustre:	Vitreous, greasy
Common form:	Crystal aggregates, fibrous, massive, encrusting aggregates
PE:	3.49 barns/electron
GR:	229 API
Fluorescent:	-

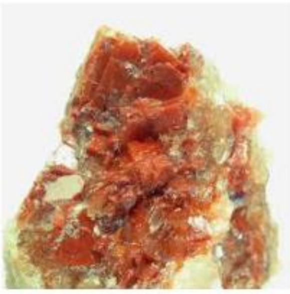

3.4 Bischofite

Chemical formula:	$MgCl_2 \cdot 6H_2O$
Crystallographic system:	Monoclinic prismatic
Cleavage:	None
Fracture:	Conchoidal to uneven
Solubility:	Very soluble (hygroscopic)
Hardness:	1.5-2.0
Density:	1.56
Colouration:	Colourless, white, transparent-translucent
Streak:	White
Lustre:	Vitreous, greasy
Common form:	Fibrous, crystalline aggregates
PE:	4.19 barns/electron
GR:	0 API
Fluorescent:	-

4.0 Sulphates

4.1 Polyhalite

Chemical formula:	$K_2Ca_2Mg(SO_4)_4\cdot 2H_2O$
Crystallographic system:	Triclinic
Cleavage:	Good
Fracture:	Conchoidal, brittle, hackly
Solubility:	Only partially soluble
Hardness:	2.5-3.5
Density:	2.78
Colouration:	Colourless, grey, white, pink, transparent-opaque
Streak:	White
Lustre:	Vitreous, greasy
Common form:	Fine-granular, masses, fibrous, compact, foliated, rarely tabular, pseudo-orthorhombic
PE:	4.30 barns/electron
GR:	178 API
Fluorescent:	-







4.2 Langbeinite

Chemical formula:	$K_2Mg_2(SO_4)_3$
Crystallographic system:	Cubic, Isometric, Tetartoidal
Cleavage:	None
Fracture:	Conchoidal, very brittle
Solubility:	Slowly dissolves in water.
Hardness:	3.5-4.0
Density:	2.83
Colouration:	Colourless, white, yellowish, greenish, violet, grey
Streak:	White
Lustre:	Vitreous
Common form:	Fine-granular, crystalline aggregate, nodules, disseminated grains, bedded massive.
PE:	3.54 barns/electron
GR:	270 API
Fluorescent:	-





4.3 Anhydrite

Chemical formula:	Ca(SO4)
Crystallographic system:	Orthorhombic
Cleavage:	Good
Fracture:	Conchoidal, very brittle
Solubility:	-
Hardness:	3.5
Density:	2.97
Colouration:	Colourless, white, yellowish, grey
Streak:	White
Lustre:	Vitreous, pearly, greasy
Common form:	Fine fibrous, crystalline aggregates, rare tabular and prismatic crystals. Usually occurs as fibrous, parallel veins that break off into cleavage fragments. Also occurs as grainy, massive, or nodular masses.
PE:	5.03 barns/electron
GR:	0 API
Fluorescent:	Some fluorescence, more fluorescence after heating






4.4 Gypsum

Chemical formula:	$CaSO_4 \cdot 2H_2O$
Crystallographic system:	Monoclinic
Cleavage:	Perfect
Fracture:	Conchoidal, splintery to parallel
Solubility:	Moderately water-soluble, less so at higher temperature
Hardness:	1.5-2.0
Density:	2.31-2.33
Colouration:	Colourless to white; may be yellow, tan, blue, pink, brown, reddish brown or grey due to impurities
Streak:	White
Lustre:	Vitreous to silky, pearly, waxy
Common form:	Gypsum occurs in nature as flattened and often twinned crystals, and transparent, cleavable masses called Selenite
PE:	3.97 barns/electron
GR:	0 API
Fluorescent:	Some fluorescence

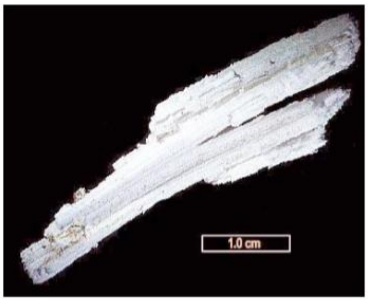
Gypsum is the hydrated version of Anhydrite.






4.5 Epsomite

Chemical formula:	$MgSO_4 \cdot 7(H_2O)$
Crystallographic system:	Orthorhombic
Cleavage:	Good
Fracture:	Conchoidal, very brittle
Solubility:	Soluble
Hardness:	2.0-2.5
Density:	1.67
Colouration:	Colourless, white, yellowish, pinkish
Streak:	White
Lustre:	Vitreous pearlescent
Common form:	Acicular crystals, fibrous
PE:	1.14 barns/electron
GR:	0 API
Fluorescent:	Non-fluorescent

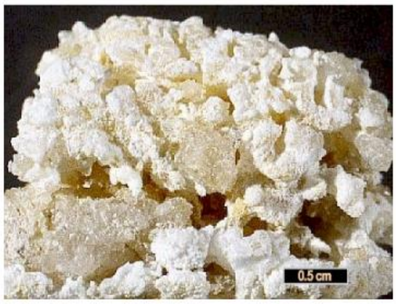






4.6 Kieserite

Chemical formula:	$MgSO_4 \cdot H_2O$
Crystallographic system:	Monoclinic prismatic
Cleavage:	Perfect one plane
Fracture:	Uneven
Solubility:	Deliquescent – turns to Epsomite
Hardness:	3.5
Density:	2.57
Colouration:	Colourless, white, yellowish, pinkish, translucent
Streak:	White
Lustre:	Vitreous
Common form:	Massive, granular masses
PE:	1.82 barns/electron
GR:	0 API
Fluorescent:	Non-fluorescent







5.0 Carbonates

5.1 Calcite

Chemical formula:	CaCO3
Crystallographic system:	Hexagonal scalenohedral
Cleavage:	Perfect in three planes
Fracture:	Conchoidal
Solubility:	Soluble in dilute acids
Hardness:	3.0
Density:	2.71
Colouration:	Colourless or white, also gray, yellow, green
Streak:	White
Lustre:	Vitreous to pearly on cleavage surfaces
Common form:	Crystalline, granular, stalactitic, concretionary, massive, rhombohedral.
PE:	5.06 barns/electron
GR:	0 API
Fluorescent:	May fluoresce red, blue, yellow, and other colours




5.2 Magnesite

Chemical formula:	$MgCO_3$
Crystallographic system:	Trigonal
Cleavage:	Perfect
Fracture:	Conchoidal
Solubility:	Effervesces in hot HCl
Hardness:	3.5-4.5
Density:	3.0-3.2
Colouration:	Colourless, white, pale yellow, pale brown, faintly pink, lilac-rose
Streak:	White
Lustre:	Vitreous
Common form:	Usually massive, rarely as rhombohedra or hexagonal prisms
PE:	0.83 barns/electron
GR:	
Fluorescent:	Blue fluorescence



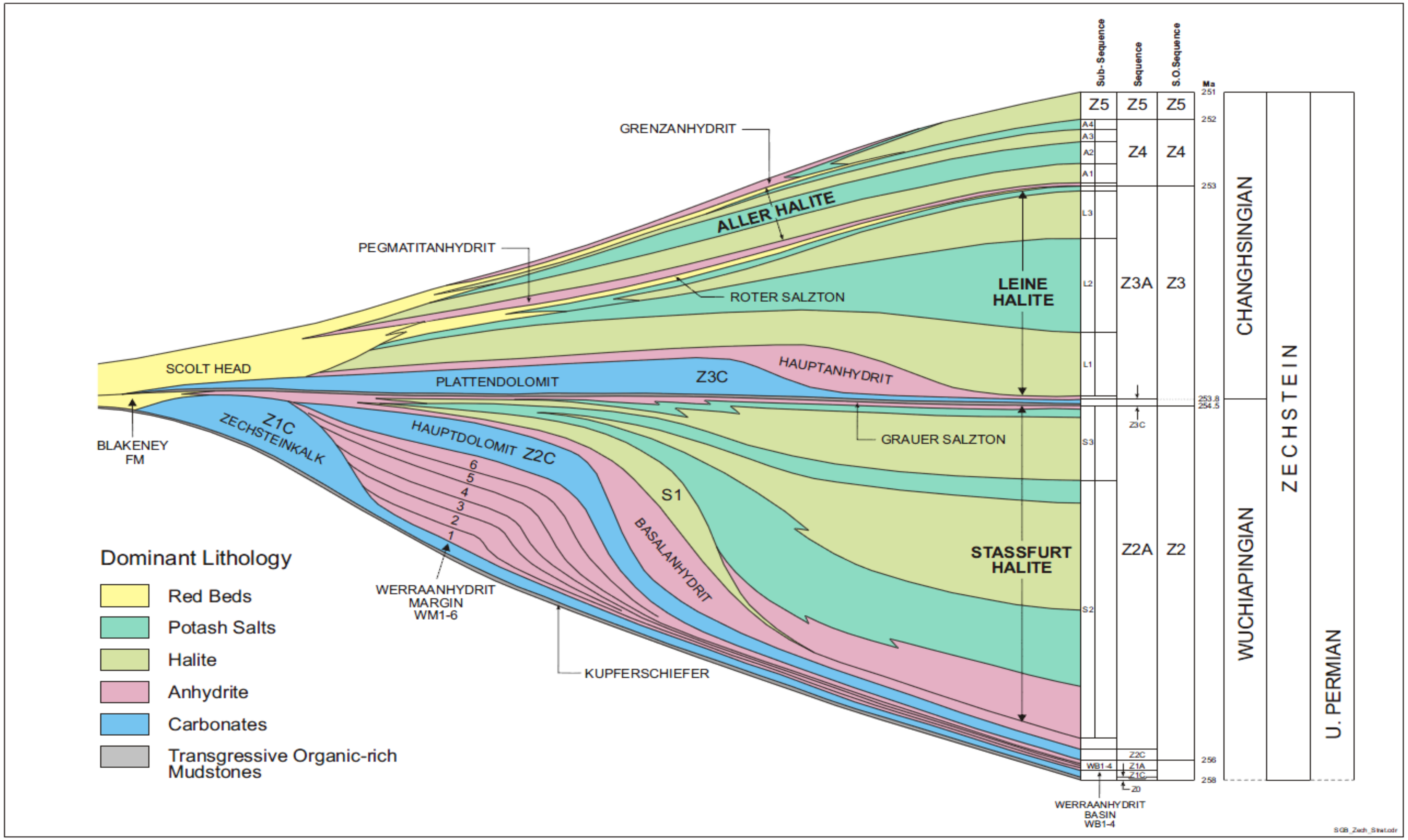



5.3 Dolomite

Chemical formula:	$CaMg(CO_3)_2$
Crystallographic system:	Trigonal, Rhombohedral
Cleavage:	Perfect on rhombohedral
Fracture:	Conchoidal
Solubility:	Poorly soluble in dilute HCl
Hardness:	3.5-4.0
Density:	2.84-2.86
Colouration:	White, grey to pink
Streak:	White
Lustre:	Vitreous to pearly
Common form:	Tabular crystals, often with curved faces, also columnar, stalactitic, granular, massive
PE:	3.13 barns/electron
GR:	15 API
Fluorescent:	Non-fluorescent

6.0 Characteristics of Evaporite Minerals

Mineral	Formula	Colours	Taste	Solubility in Water	Remarks	Specific Gravity	Apparent Log Density	Sonic µsec/ft	Neutron 'Limestone' Porosity	Gamma Ray API	Remarks
Anhydrite	$CaSO_4$	(White), Light Coloured	No	No	White precipitate with $BaCl_2$	2.96	2.98	50.0	0	0	Slow drilling. No washouts
Bischofite	$MgCl_2.6H_2O$	Colourless, White	Bitter	Sol	Evaporates in Air	1.60				0	Washouts
Carnalite	$KCl.MgCl_2.6H_2O$	White, (Red), (Yellow)	Bitter	Sol	Evaporates in Air	1.61	1.57	78.0	65	200	Washouts
Gypsum	$CaSO_4.2H_2O$	White	No	No	Platy crystals	2.32	2.35	52.5	49	0	Above 1500-2000ft depth
Halite	NaCl	Colourless, Glassy	Salty	Sol		2.17	2.03	67.0	0	0	
Kainite	$MgSO_4.KCl.3H_2O$	Colourless, White, Light Coloured	Salty, (Bitter)	Sol	Very fine grained	2.13	2.12		45	225	
Kieserite	$MgSO_4.H_2O$	Colourless, White, Light Coloured	No	(Sol)	Angular pieces	2.57				0	Secondary, often with Sylvite
Langbeinite	$K_2SO_4.2MgSO_4$	White, Colourless, (Pink)	No	(Sol)		2.83	2.82	52.0	0	275	Rare
Polyhalite	$K_2SO_4.MgSO_4.2CaSO_4.2H_2O$	(Grey), White, (Yellow), (red)	No	(Sol)	Leaves Gypsum precipitate in Water	2.78	2.79	57.5	15	180	Often secondary after Anhydrite
Sylvite	KCl	Colourless, White, Light Coloured	Bitter, (Salty)	Sol	Often turbid, cloudy	1.96	1.86	74.0	0	500	



Zechstein Stratigraphy and diagramatic shelf to basin profile, UK Southern North Sea,
(Adapted from Taylor 1984; Knox and Cordey 1994; Menning 1995; Jun et al 1997; Glennie et al 2003)

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