Triassic Salt Deposits in Southern England

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ABSTRACT

The best known salt occurrences in southern England are located in Somerset. These deposits, first discovered in 1910 during a search for coal, were exploited for a short period in succeeding years. The Somerset salt-field was investigated by the Institute of Geological Sciences in 1971, when a continuously-cored borehole was sunk to a depth of over 1,100 m and proved four horizons of rock salt through a saliferous sequence some 50 m or more thick. The salt deposits are present in red mudstones and siltstones of the Keuper Marl (Triassic), and halite is the principal evaporite mineral; potassium minerals are unknown. The halite occurs in the Central Somerset Basin, part of an elongate, narrow trough into which sedimentary formations thicken. The trough is considered to be a fault-bounded rift or graben which was initiated at the close of the Variscan Orogeny and which experienced a long, continuous development during the Mesozoic. Other salt deposits of Triassic age are located beneath some parts of southern England and their occurrence is probably restricted to narrow, fault-bounded troughs, in a general situation similar to the Somerset halite. The evaporite deposits are bedded with the Keuper Marl sediments and no halokinetic structures are known with certainty, although some structures in overlying Jurassic rocks have, in the past, been attributed to movement of Triassic salt. Delineation of graben structures, from the disposition of overlying rocks, may allow possible location of evaporite deposits where the appropriate (Keuper Marl) facies is present.

INTRODUCTION

Triassic rocks in southern England, south of the latitude of Birmingham, crop out to the west of the Jurassic escarpment and fringe the Palaeozoic massifs of Wales and Cornubia. The cover of later Mesozoic rocks, however, masks a more extensive subsurface distribution which is understood moderately well from deep borings and geophysical work. Thus the Triassic deposits are known to pinch out eastwards against the London Platform, where they are overlapped by later Mesozoic rocks. The Triassic rocks occur in two major basinal structures, the Worcester Basin, sometimes known as the Severn Basin, and the Wessex Basin (Kent, 1949). As an offshoot to the west of the Wessex Basin may be considered the Central Somerset Basin, which is continued westwards beneath the waters of the Bristol Channel.

The red beds of the British Trias are traditionally classified into two major parts, a lower Bunter division and an upper Keuper division which are, in turn, further subdivided. The rocks normally assigned to the Bunter comprise sandstones, with important insertions of conglomerates or pebble beds, and do not yield economically important evaporite deposits; they are thus excluded from further discussion. The Keuper division traditionally includes a lower series of predominantly arenaceous strata and an upper series mainly of 'marls' (the Keuper Marl) but with other lithologies present. Until relatively recently, the near absence of macrofauna from the Triassic red beds led workers to correlate the lithological divisions with units of the same name in Germany, but work on the microfloras (Warrington, 1970; 1974a) has shown that the "Keuper" Sandstone of England is of late Scythian, Anisian and early Ladinian age while the Keuper Marl, up to and including the Arden Sandstone horizon, is of younger Ladinian and Carnian age. The Norian stage may be represented by part of the Keuper Marl above the Arden Sandstone horizon but the precise limits of the overlying Rhaetian stage are not well defined as yet. Thus the use of the terms Bunter and Keuper, which, in English geological literature, have acquired time connotations, is unfortunate and new lithostratigraphical terms will be proposed by the Geological Society of London in a forthcoming publication. For present purposes the English "Keuper" can be subdivided as follows.

Keuper { Keuper Marl
Keuper Sandstones

It is important to remember that the prefix "Keuper" carries no time connotation. Within the Keuper Marl are important evaporite deposits, but the main lithologies are brownish red, slightly calcareous siltstones or silty mudstones with green bands, patches and spots; subordinate sandstone horizons (e.g. the Arden Sandstone and its equivalents) are also found locally.

Deposits of halite within the Keuper Marl are known from the Worcester Basin area and the Wessex Basin area. For the purposes of this account, however, only Triassic halites of the onshore area south of an E–W line through London and Bristol are considered, despite the fact that well-known occurrences of Triassic halite are documented from the Droitwich area of the Worcester Basin (Sherlock, 1921; Mitchell and others, 1962).

HALITE IN SOMERSET

The best-known development of Triassic halite in southern England occurs in Somerset, south of the Mendip Hills. Prior to 1910 the presence of halite deposits was quite unexpected in this area, as much of the solid geology of the flat and low-lying fenland of the Somerset Levels is obscured by Recent alluvial deposits. A report on the possibility of finding workable coal seams to the south of the well-established Somerset coalfields (north of the Mendip Hills) induced several local entrepreneurs to invest money in a deep borehole at the village of Puriton near Bridgwater. The cored borehole (McMurtrie, 1911) failed to reveal what was beneath the New Red Sandstone (Permo-Trias) and was abandoned at a depth of 631 m without proving coal, but it demonstrated the presence of halite in the Triassic Keuper Marl. Subsequent to this, brine was pumped and treated at Puriton (Whittaker, 1970) for a period of eleven years. It is known from Geological Survey archive material that four other boreholes were drilled to the halite shortly after the original discovery, but the records of these wells are lost.

The first Puriton borehole was located approximately at British National Grid Reference ST 3191 3088 and proved about 35 m of halite and halite-bearing marl between the depths of 181 m and 216 m. From the descriptions of McMurtrie (1911) and Ussher (1911) it is clear that the rock had a 'cindery' appearance at the top and that there had been solution of the halite to some depth. The halite deposits were enclosed in marl with a 'broken, brecciated appearance', an appearance which was enhanced, no doubt, by the use of fresh water for drilling. The early descriptions of the Puriton halite are inadequate for modern use but it is clear that the lithologies and geological setting are similar to those proved elsewhere in Somerset (see below). Analyses of the Puriton halite and brine were presented by McMurtrie (1911) and Sherlock (1921). It is impossible to estimate the proportion of halite to marl in the Puriton deposits, but a similar broad stratigraphy to the Burton Row halite occurrences is evident. The relative stratigraphical position of the Puriton halite within the Keuper sequence can be fixed with reference to the Rhaetic deposits, which crop out close by at Puriton Hill.

In 1971, the Institute of Geological Sciences sank a cored borehole which proved the northward extension of the Puriton halite beds. This borehole, located at Burton Row, Brent Knoll (National Grid Reference ST 3356 5208), was drilled to investigate the Mesozoic stratigraphy of the Central Somerset Basin, where much of the solid geology is obscured by alluvial deposits. The borehole proved some 53 m of halite-bearing marl at a similar stratigraphical level to that proved at Puriton and it is considered that the bedded halite deposits are present, at depth, in the area between the two borehole localities (Whittaker, 1972). The Permo-Triassic sequences of both boreholes are similar, and at Burton Row the Keuper Marl comprises typical brownish red siltstones, with green bands.

Pink colored veins of halite were first encountered at 643 m depth and became particularly abundant just above the top of the main saliferous beds at 693.76 m where the Keuper siltstones had a sponge-like or 'cindery' appearance. Bedded, colorless and pink halite, with varying proportions of 'marl' was present between 693.76 m and 742.40 m depths; halite veins and stringers occurred below the main saliferous horizons down to a depth of 797 m. Varying proportions of siltstone or 'marl' were present in the halite, but four horizons were noted in which the evaporite predominated in quantity over 'marl'. The four horizons are readily identified on geophysical wireline logs and caliper logs of the borehole. A summary of the saliferous beds of the Burton Row borehole sequence is given in Table 1.

The percentages of marl and salt given above are visually estimated from the cores. As with the Puriton succession there are few or no beds of pure halite, and an admixture of marl invariably contaminates the salt.

Stratum contours on the top surface of the Keuper saliferous beds of Somerset show a broad synclinal structure with a more steeply-dipping northern limb. The depth to the top of the halite deposits, relative to sea level, ranges from −152 m on the flanks of the syncline to −609 m in its axial region. The syncline is crossed by important ESE-trending normal faults with younger strata preserved in the trough. Dry rock-head conditions were proved in the Burton Row borehole although there was evidence of contemporaneous solution giving a sponge-like appearance to the marl at the top of the main salt beds. The old records from Puriton, however, suggest that wet rock-head conditions may be present at this locality, implying groundwater circulation to

TABLE 1

Sequence of Salt Bearing Beds of the Burton Row Borehole

	Unit	Thickness m	Depth m
	Keuper Marl present above the saliferous beds from base of Rhaetic	221.70	693.76
Bed 1	Halite with 'cindery' marl patches making up about 20% of the total rock	8.04	701.80
Bed 1	Siltstone with reddish pink halite making up about 40%–45% of the total rock	1.26	703.06
Bed 1	Halite, with marl making up about 15% of the total rock	0.74	703.80
	Siltstone, with up to 40% halite in places	8.35	712.15
Bed 2	Halite with about 20% marl	2.96	715.11
	Siltstone with much halite veining	12.18	727.29
Bed 3	Halite with marl making up 10%–20% of the total rock	5.07	732.36
	Siltstone with some halite veins and masses	7.14	739.50
Bed 4	Halite with up to 40% marl	0.95	740.45
Bed 4	Siltstone with halite veins and masses	1.25	741.70
Bed 4	Halite with about 20% marl	0.50	742.20

the depth of 180 m or more. The halite occurs beneath at least 90 sq. kilometers of this part of Somerset but the eastern and western limits are not known with certainty.

Halite is the principal evaporite mineral occurring in the Somerset Keuper Marl and is developed mainly as haselgebirge (used here to denote a lithology with randomly orientated crystals of halite set in a matrix of red terrigenous sediment). The detailed petrography will be described elsewhere. Other evaporite minerals in the Somerset Keuper Marl sequence include anhydrite and gypsum occurring as isolated nodules or as lines of nodules parallel to bedding; the nodules may or may not be interconnected along the bedding. Visual inspection of cores and examination of gamma-ray wireline logs show that no potassium minerals are associated with these Keuper halite beds.

THE CENTRAL SOMERSET BASIN

The Keuper saliferous beds of Somerset occur in the Central Somerset Basin (Green and Welch, 1965; Whittaker, 1973), an important ESE-trending synclinal structure. This synclinal structure is bounded to the north by the Mendip Hills, which are composed of folded and faulted Carboniferous Limestone, and to the south by the Quantock-Cannington massif, which is composed of intensely folded and faulted Devonian and Carboniferous strata. The ESE-trending Central Somerset Basin between these Palaeozoic 'highs' is continued to the west beneath the waters of the Bristol Channel (see Lloyd and others, 1973) and to the east as the Glastonbury Syncline (see Jones, 1930). This elongate narrow furrow or tectonic depression, preserving thick Mesozoic rocks, is traceable for at least 160 km along the strike. Until relatively recently it was thought that this tectonic depression came into existence as a result of Miocene folding, but it is now clear that fracturing on an important scale has played a significant role in its development. Studies of the Central Somerset Basin and its adjoining areas show that the basin is not only a structural syncline, but was also a depositional basin into which many of the Mesozoic formations thicken from the margins towards the axial region. The palaeozoic rocks which form the framework of the basin are well-known at outcrop and reach heights of well over 300 m above sea level; by contrast, the palaeozoic rocks forming the floor of the basin have never been penetrated, despite the drilling of boreholes to levels of −1100 m or so relative to sea level.

Notwithstanding the alluvial cover of the Somerset Levels, solid rocks crop out in several places, and numerous shallow boreholes have been sunk through the drift deposits into fossiliferous Jurassic rocks. This has enabled the broad outlines of the geological structure to be defined. The available evidence indicates that the Central Somerset Basin is a rather steep-sided and relatively flat-bottomed feature, which suggests that the structure may have been initiated as a rift in the palaeozoic rocks in late Variscan times. Furthermore, stratigraphical thicknesses change abruptly in the vicinity of the swells (or horsts) which frame the basin, and some facies changes occur. This differential subsidence of the trough throughout Permo-Triassic and early Jurassic times indicates that it was developing progressively during the early Mesozoic and that the bounding faults of the postulated rift were active during these times. Thus the elongate, narrow depression is characterized by thick sequences developed in an essentially fault-bounded synclinal structure which has been subsequently folded and faulted by post-Mesozoic movements. It seems likely that post-Mesozoic movements would accentuate earlier intra-Mesozoic structures as well as initiating new structures.

At the margins of the basin, in Permo-Triassic times, there was overlap of older by younger formations so that the area of sedimentation was increasing as time proceeded. For instance, the "Keuper" Marl, which overlaps earlier Permo-Triassic deposits and comes to rest directly, and of course unconformably, on Palaeozoic rocks, thickens from 150 m near the margins of the basin to over 600 m near the depocentre. Clearly, the basin area was subsiding at a faster rate than adjacent areas. The halite-bearing beds of the Keuper Marl are restricted to the basinal area and stratum contours of these measures reflect the elongate, ESE-trending broad synclinal structure of the main basin. Isopachytes of the saliferous beds show an increase from about 35 m near the margin of the basin to perhaps over

100 m near its ESE-trending long axis. The halite-bearing strata may 'wedge out' at the northern and southern margins of the basin but stratigraphical relations are not clear in these areas because of the ubiquitous drift cover and development of possible wet rock head conditions in outcrop situations.

OTHER TRIASSIC HALITE DEPOSITS BENEATH SOUTHERN ENGLAND

The Keuper Marl crops out south of the Central Somerset Basin as far as the south coast of Devon, near Sidmouth. It is also present east of this line but is largely concealed by a cover of younger rocks in the Wessex Basin (sometimes referred to as the Hampshire-Dorset Basin). Some information has been obtained on the concealed Triassic of this area but much of it is not available to the general public. Keuper Marl is thought to be present as far east, roughly, as the western Weald (Audley-Charles, 1970; Warrington, 1974b), but it varies markedly in thickness from place to place. Halite deposits within the Keuper Marl appear to be restricted to certain elongate, narrow areas or zones in which thick successions are present. From the study of geophysical wireline logs it appears that the halite deposits of this region are very similar to those of Somerset; that is they take the form of a haselgebirge mixture of halite and red terrigenous detritus usually in discrete beds which are rich in halite. The Somerset stratigraphical pattern with between 200 m and 300 m of Keuper Marl intervening between the base of the Rhaetic and the top of the saliferous beds, where present, is maintained in the Wessex Basin although this thickness is locally somewhat greater. The thickness of the Keuper saliferous beds varies a little under parts of the Wessex Basin but is of the same order of magnitude as the halite beds of Somerset, that is the thickness ranges to over 100 m.

A striking feature of the Wessex Basin Triassic halite occurrences, where present, is their essential similarity to the Somerset deposits. As in Somerset, there is no direct indication of halokinesis, only of halite bedded with the argillaceous Keuper sediments. This may be due to their restricted distribution in deep, narrow troughs, coupled with the presence of predominantly haselgebirge fabric (i.e. the lack of beds of pure halite).

The well-known linear tectonic structures of the south Dorset area (Wessex Basin) developed at the surface in Jurassic, Cretaceous and Lower Tertiary rocks, have in the past been partly attributed to the presence of rock salt at depth (Arkell, 1947). Parts of the Wessex Basin are characterized by major east-west anticlinal fold structures which commonly have gently-dipping or almost undisturbed southern limbs, but steeply-dipping northern limbs which are associated with faulting. The steeply-inclined limbs of these essentially monoclinal structures invariably face north and have a complementary synclinal structure with Lower Tertiary sediments adjacent to them. The more intensely disturbed zones of these structures in many places comprise sets of smaller-scale folds and faults which are arranged en echelon. Arkell (1947, p. 248) remarked that Stille, on a visit to Dorset, was reminded of the tectonics of the Hanover region, where comparable structures are associated with salt movement, and he quoted a suggestion by G.M. Lees and P.T. Cox that the Dorset folds may be formed over a salt series of Triassic or even Permian age which may have facilitated the development of the observed tectonic structures. These suggestions were made at a time when nothing was known of Triassic halite deposits beneath the Wessex Basin. Not enough detail is known of the distribution of the halite properly to assess the possible role of halokinesis in the development of the post-Variscan structures of this part of southern England, but in the present state of knowledge it seems unlikely that such movement has played a major part in this development, although it may have contributed some local effects.

DISCUSSION

The Triassic halite beds of southern England correlate broadly with those of Division 4 of Audley-Charles (1970), a division which includes the important evaporite-bearing Triassic beds of central and northern England. The occurrence near the top of the Somerset saliferous beds of the North Curry Sandstone, which correlates with the Arden Sandstone of the English Midlands (see Ussher, 1911; Warrington, 1970), suggests that the southern England Triassic halite-bearing beds probably equate with the Harlequin Formation of Nottinghamshire (Elliott, 1961), the Upper Keuper Saliferous Beds of Cheshire (Evans and others, 1968) and the Gipskeuper of Saxony; thus a Carnian age is probable by analogy with data from these areas (Geiger and Hopping, 1968; Warrington, 1970).

The similarities between the Triassic halite deposits of Somerset and those of the Wessex Basin, in terms of stratigraphy and composition, suggest a similar genesis and history. It has been argued (Whittaker, 1975) that a major rift system is present in the Palaeozoic rocks of southern Britain, with graben structures underlying the Bristol Channel, the Severn Basin and the Jurassic trough of the Weald. Some of the postulated rifts have a long narrow form and contain thick Mesozoic sequences; they display marginal facies changes and classic features of overlap and are associated with the occurrence of Triassic salt deposits. A similar model of elongate, narrow troughs or depressions affecting the disposition and distribution of the Mesozoic rocks, seems applicable to the more southerly parts of the Wessex Basin. By analogy with other Mesozoic troughs in general, and with the Somerset basin in particular, it may prove to be possible to locate occurrences of Triassic salt deposits beneath the deeper, unexplored parts of the Wessex Basin. Search for possible surface drape folds and similar structures, which possibly overlie zones of deeper faulting or disturbance, and adjacent thick Mesozoic sequences, may make it possible, as suggested by Warrington (1974b, 1976), to delineate areas of potential interest for the location of Triassic salt deposits, providing the appropriate argillaceous (Keuper Marl) facies is present.

DISCUSSION

I. Zak:

Question. Similar geological history, during same Upper Triassic period, is displayed throughout the Levant. There, sequences of gypsum and anhydrite (though with little remnants of halite, in the northeast) differing in thickness, emphasize basins of subsidence separated by regions of retarded subsidence. Basins and ranges are controlled by tectonic lines along which movement probably started already during the Permian. These are thought to be related to brittle necking of the upper continental crust close to a region of plate separation.

Shallow water sedimentary structures, repeatedly occurring throughout the region of thicker and thinner sequences, are accepted to indicate contemporaneous subsidence and sedimentation to about water level. Dessication structures and cellular limestone and dolomite, more developed within the thinner sequences, indicate occasional exposure, with collapse following dissolution of underlying evaporites, possibly also halite.

My question is whether similar or other sedimentary structures are recognized within the basin you have described and along its periphery, to support the conclusion of rate of sedimentation being controlled by differential subsidence.

Answer. Basin sediments are poorly exposed. Within the basinal areas geological information is almost entirely restricted to that obtained from subsurface sources. However, the Triassic halite-bearing beds appear to pass laterally, in places, into sulphate-rich (anhydrite, gypsum) beds developed in thinner sequences, which, broadly-speaking, show indications of shallowing or even emergence (dessication cracks).

The basinal areas are located along zones of tectonic weakness which date back to Upper Palaeozoic and probably earlier times.

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