1 Introduction

Salt, sodium chloride, is such a common substance in our lives that we tend to take it for granted. A trip to the supermarket allows us to choose between several different sorts – sea salt, rock salt, cooking salt (with added iodine); factory-processed salt, artisanal salt; home-produced salt, salt imported from the other side of the globe. Most of the time we pay no attention to it, nor do we think about where it comes from. It is just there in our lives. But it was not always thus.

Some ancient authors wrote about salt, but they generally tell us less than we would like to know about where salt came from and how it was produced. This suggests that for them too it was such a common commodity that they did not think it worth going into details. Medieval and Renaissance writers are more forthcoming, notably Georgius Agricola, writing in the sixteenth century; from them it is possible to infer much of what went before them. In fact, the production of salt was a major concern at all periods of the past, including the ancient past. In this Element, I shall describe what we know of the European production of salt from earliest times down to the Roman period.

The Importance of Salt

Humans and animals all need to consume salt in order to get an intake of sodium, which regulates the fluid balance of the body and assists with other functions of the internal organs. The fact that for many people salt adds 'savour' to food, in other words it makes bland food taste more interesting, is perhaps a fortunate stimulus to its consumption, if not a biological adaptation. How much salt is necessary for health is a matter of some debate: the figure of 6 g daily (2.4 g of sodium) is often quoted as the ideal maximum (it is the amount recommended by the NHS in Britain, for instance); larger amounts are believed to increase the risks for high blood pressure, cardiovascular disease and other problems. Eating too little salt also causes problems, though in fact most humans get enough salt through their normal diet, especially if they eat meat, eggs or fish. Animals will seek out salt if not given it as part of their diet. Experimental work in the 1960s and 70s showed how animals deprived of salt suffer ill effects that lead to poor health; sodium is needed especially for nursing young animals. This 'hunger for salt' (Denton 1984) makes animals seek out salty pools or rocks to lick, and to eat vegetation that is rich in sodium.

Salt is also crucial for other reasons, the most significant in pre-industrial societies being the preservation of food. Its antibacterial properties make it ideal for this purpose, as well as for combating infection from wounds and sores. In peasant communities it is used to this day to treat health problems such as rheumatism and arthritis. Today, however, in most of the world the uses of salt

as a foodstuff and preservative are dwarfed by those of industry and road-salting in winter, which do not apply to times before the Industrial Revolution.

Salt in the World

Salt is found commonly in the world. The largest deposits are in the Americas, Saharan Africa and parts of Asia (China and the Himalayan area); the largest producers today are China, the United States and India. In Europe, the largest producer is Germany, but several other countries have significant salt resources, notably Spain, Poland, Romania and the UK (salt is one of the few natural resources in which Britain is self-sufficient).

Much has been written about historical salt exploitation in North America and in China, while ethnographic accounts have covered Niger (Gouletquer 1975; Gouletquer & Kleinmann 1984), New Guinea (Godelier 1969; Pétrequin *et al.* 2000) and several Mesoamerican countries (Good 1995; Williams 1999). Several books and websites give excellent descriptions and images of non-industrial salt

Figure 1 Blocks of Taoudenni salt at the port of Mopti in Mali, Africa (information in accompanying text and this image 'Mopti sel' by Taguelmoust downloaded at the French language Wikipedia. Licensed under CC BY-SA 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Mopti_sel.jpg#/media/File:Mopti_sel.jpg).

production, for instance in Mali (Figure 1) (www.saltworkconsultants.com /ancient-salt-trade-and-its-value/, last accessed 14 December 2020).

In this volume my aim is to provide a short account of salt production in the ancient world, concentrating on Europe from earliest times down to the Roman period. Good accounts of salt in parts of the Americas are those by Ian Brown, Heather McKillop and Dumas & Eubanks (Brown 1981; McKillop 2002; Dumas & Eubanks 2021), while for China the best accounts in English are those by Tora Yoshida and Rowan Flad (Yoshida 1993; Flad 2011). For Africa the accounts by Paul Lovejoy (1986) and Ann McDougall's many contributions are important; there is a useful web article by Mark Cartwright on the west African salt trade (www.ancient.eu/article/1342/the-salt-trade-of-ancient-west-africa/, last accessed 10 November 2020).[1]

There are several histories of salt production and consumption (e.g. Mollat 1968; Multhauf 1978; Bergier 1982; Adshead 1992; Kurlansky 2002) and several important books by the historian Jean-Claude Hocquet (e.g. Hocquet 1978–9; 2001; 2019). His 2001 book is an excellent introduction to the theme, with marvellous photographs of salt production in many parts of the world.

The story in Europe goes back millennia, and in technological terms is varied and often complex. In the sections that follow I shall look at these matters in detail.

2 What Salt Is, Where It Occurs and How It Is Exploited

Sodium chloride, common salt, is an evaporite mineral, that is, one that is concentrated or crystallised from an aqueous solution, either the oceans, or lakes such as the Dead Sea or the Great Salt Lake in Utah. Through evaporation, over geological timescales, rock salt (halite) is created. Salt in rock form is found in the form of diapirs, dome-like structures arising from ancient seawater deposits, protruding upwards and sometimes appearing on the earth's surface. In mountainous areas, these domes have been subjected to various tectonic processes that have resulted in them being uplifted, so that the salt rock appears at or near the surface. The presence of underground diapirs is also responsible for the emergence of salt-water springs that emerge into the light of day without any rock salt being apparent, as rainwater and other underground water is forced upwards.

Salt is found widely in the world. In this Element, I am concerned principally with Europe, where salt occurs in many areas (Figure 2). The largest area is that spreading across the north of the continent, from northern England through Germany and Poland, but there are many other areas that are rich in deposits,

[1] These are only a few of the many books and articles on salt in different parts of the world.

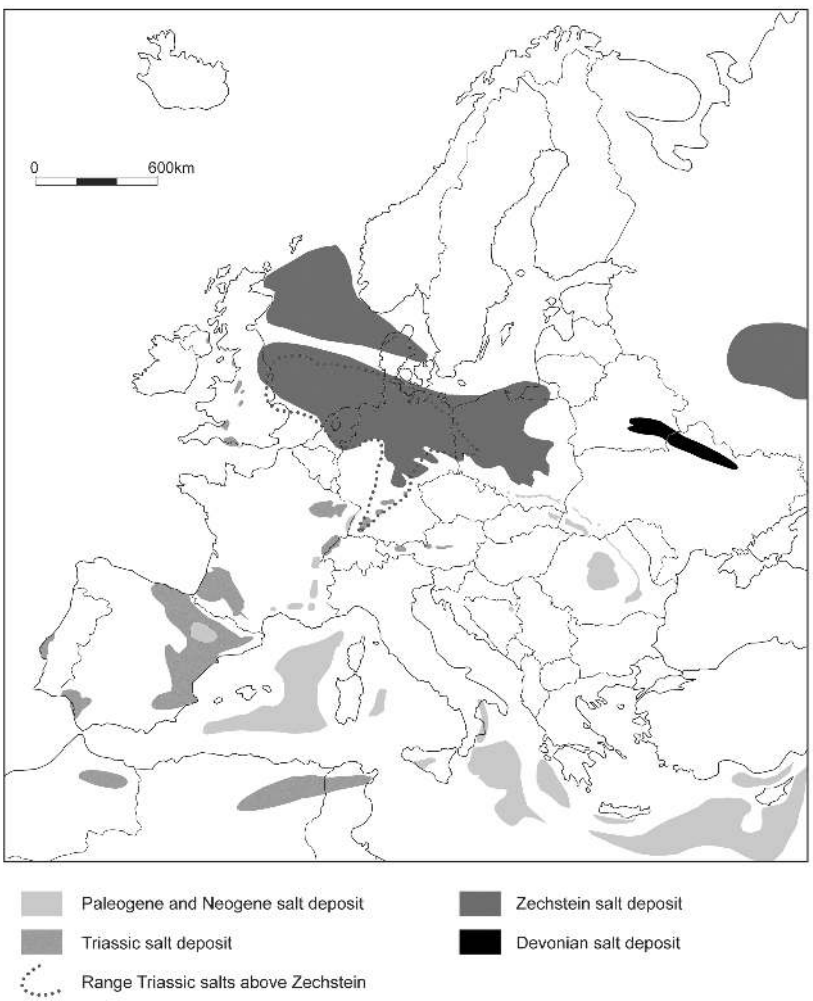


Figure 2 Map of Europe showing the major salt areas and their geological age.
Source: Harding 2014.

notably the Carpathian area, where the 'foredeep' extends from southern Poland through western Ukraine, touching on northern Romania. Another area with many salt deposits occurs in the Alps, particularly in Austria; also in France, Spain, Turkey and elsewhere. Of course concentrating on rock salt and inland salt-water springs ignores the other main source of salt: the sea. The salt content of seawater is typically around 3.5 per cent (i.e. 35 g of salt in 1 litre of water); extracting it through evaporation is crucial for coastal communities, in the past as nowadays. Salt lakes can contain much more salt: the Dead Sea, for instance,

is around 340 g/l saline, the Great Salt Lake of Turkey (Tuz Gölü) up to 324 g/l, compared with the Adriatic at 33 g/l, or the Black Sea at only 18 g/l.

Although Europe as a whole is rich in salt, individual parts of it are not. This is very significant in historical and economic terms, since it means that those parts with no access to salt had to obtain it from neighbouring or more distant areas.

Exploitation of Salt Sources

Salt may be produced in a number of different ways, most of which were utilised in prehistoric Europe. Which method was used will have depended on the nature of the deposit to be exploited.

In general, salt is obtained either by mining and quarrying or through the evaporation of saline liquids (brine or seawater). Most forms of exploitation in antiquity utilised one or other of these forms of salt: as Pliny the Elder said, 'all salt is artificial or native', the distinction between *sal nativus* (rock salt) and *sal facticius* (salt obtained through human action). It is also possible to obtain salt from halophyte plants (plants that tolerate salty conditions, found growing on salty soils), which can be burnt on a fire and the salt crystals picked off. Salty mud or marsh can also be used, through a process of filtration or leaching known as lixiviation. Archaeologically speaking, both the extraction of rock salt and the boiling of salt water leave clear traces in the archaeological record. The burning of plants is not visible archaeologically, but may be assumed to have happened, since it is well known in ethnographic situations.

Quarrying and Mining

The simplest method in technological terms, in the case where rock salt outcrops on the surface, is simply to break lumps of salt off the rock body. This involves no equipment other than strong hammers. This is, however, somewhat easier said than done. The rock surface may be very hard – indeed, if it occurs on the earth's surface, it is bound to be, as otherwise it would dissolve and wash away through weathering.

Where rock salt outcrops on the earth's surface, it would be natural for ancient people to exploit it, since it can be used with little manipulation; it can be ground down to a form that can be used directly, or it can be dissolved in water and then evaporated using heat to produce salt in crystalline form. In practice, there are rather few known locations in Europe where rock salt was exploited directly; either because there are few such outcrops easily detectable or because the rock is extremely hard, making working it time-consuming and

laborious, or both. Instead it is the exploitation of brine springs and streams, or of seawater, that accounts for the largest amount of evidence for salt production from the ancient world.

In prehistoric times, the extraction of salt in rock form is known above all from the great mining sites of Hallstatt and Hallein in Austria, though there are other locations in the German and Austrian Alps where salt is present, for instance Bad Reichenhall in Bavaria or Hall in Tirol in Austria. Even there, the method of exploitation does not only involve the extraction of hard rock, as I shall discuss in the following. There are many parts of modern Romania, especially in Moldavia and Muntenia (the eastern and south-eastern provinces of that country) where salt can be seen outcropping in great massifs (Figure 3). It would seem inconceivable that such outcrops were not exploited in ancient times, but since they continue to be exploited on a small scale to the present day, any trace of ancient activity has been lost.

Modern rock salt mines are deep, far deeper than would have been technologically possible in prehistory. One can visit such places in parts of Germany, Poland, Romania and Spain; nowadays one is transported down many tens of metres in lifts, which brings home the impossibility of such processes being possible in ancient times. Instead, the rock would have been worked from the surface, in effect in a form of quarrying. The Romans, by contrast, developed sophisticated techniques for deep mining, using a range of technologies for

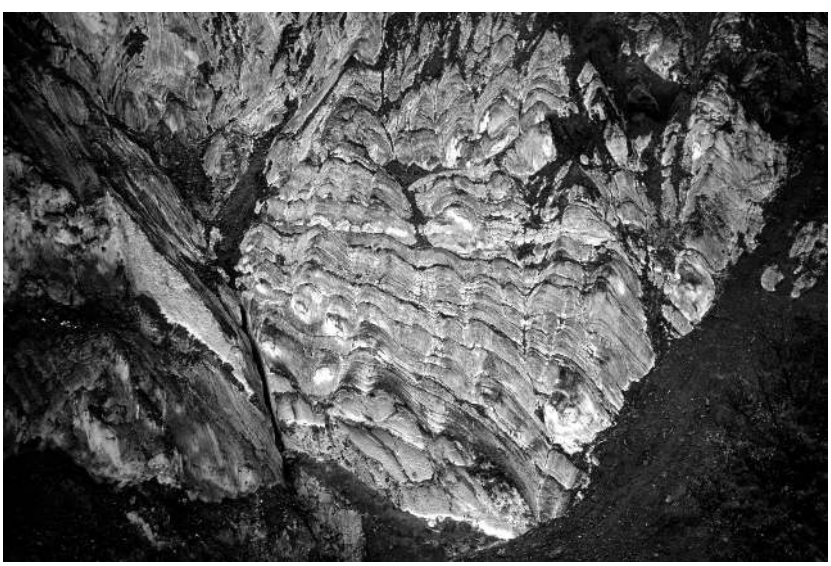


Figure 3 Rock salt at Bisoca, Muntenia, Romania.

Photo: author.

pumping out water and providing means of getting miners in and mined material out. These are best known from Spain in the context of metal extraction, but there is evidence for their use in the province of Dacia too.

Rock salt is hard, so that extracting it with pre-industrial technology is a significant obstacle. My own experience in dealing with rock salt in fieldwork in Romania shows how hard the rock may be and how laborious breaking it up is. I have seen local people working with heavy iron hammers and picks on outcrops in Buzău county in Muntenia (specifically in the area around Bisoca and Mânzăleşti), getting lumps of rock to provide salt lick for their animals; and a colleague, Andrea Chiricescu, working at the time for the Museum of the Eastern Carpathians in Sf. Gheorghe, filmed a man working a rock surface at the village of Dumitra near Bistrița in the north of Transylvania. He was using a heavy iron pick to strike the rock surface, but it took him fifteen minutes to remove a block of salt a few kilos in weight (plus numerous small chips). On another occasion, at the site of excavations at Băile Figa near Beclean in the same county, a bulldozer which was being used to remove the overburden could only scratch the surface of the rock salt with the teeth of its bucket.

The implications for the prehistoric exploitation of rock salt are obvious: suitable hard stones (or, in later times, bronze or iron picks and hammers) must have been used, presumably mounted firmly onto hafts and secured with bindings of leather or fibrous vegetable matter (clematis or similar). It must, however, have been a long and tedious process to get any reasonable quantity of rock – which would then need to be processed by grinding or dissolving and re-evaporating.

In general, one might presume that wherever rock salt appeared on the surface, people would have wished to exploit it. Archaeologically speaking, this presents a difficulty, in that such working is most unlikely to leave any traces. Only the presence of suitable hammers or grinding stones might indicate the existence of such work. But this is to ignore some of the most important and prolific sites where rock salt exploitation took place: the mining sites of the Austrian Alps, above all Hallstatt and the Dürrnberg near Hallein.

Hallstatt, which has been subject of extensive investigation in recent years, is rightly regarded as one of the most important salt production sites in prehistoric Europe. The extensive workings lie alongside an upland valley on the Plassen mountain above the eponymous lake (Figure 4), and are adjacent to the famous Iron Age cemetery whose contents gave their name to the period between *c.*1200 and 700 BC. The different parts of the mining area belong to different periods; the Bronze Age workings are mainly in the northern area, while in the eastern and western areas the remains belong to the early Iron Age. In both, it was necessary to engage in deep mining, cutting shafts and adits to create tunnels into the mountain.

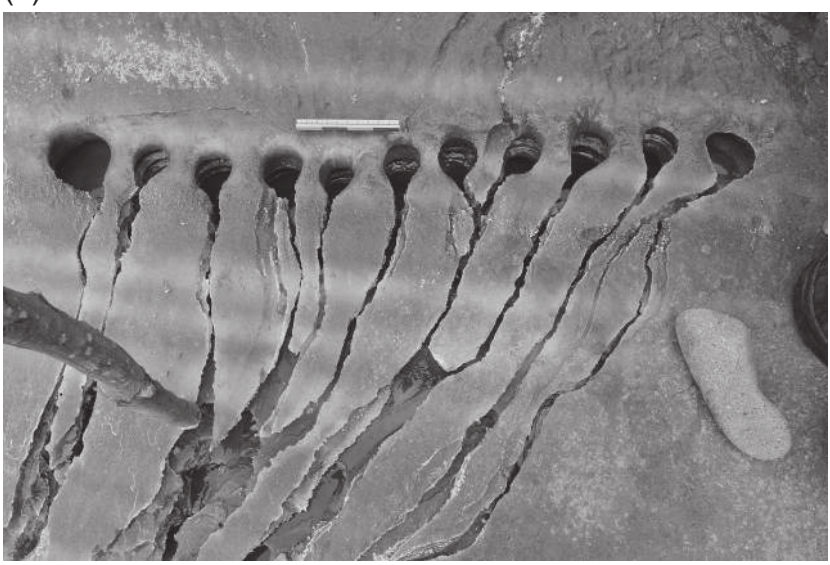
Figure 4 Aerial view of Lake Hallstatt, showing the town and the plateau where the Iron Age cemetery and salt mine are located.

Photo: courtesy of Luftbildarchiv/Institut für Ur- und Frühgeschichte Wien.

At the working surface, the miners used picks to extract the rock. The precise technique adopted differed remarkably between the Bronze and the Iron Age. In the Bronze Age, deep parallel grooves were hacked into the rock surface and the intermediate material hammered out in lumps or chips. In the Iron Age, the picks were used to create heart-shaped blocks which were removed whole, with as little waste as possible. In both cases, the rock was moved from the working surface for further processing; in medieval and modern times this principally means dissolving the salt in water and evaporating it, with the aim of removing the unwanted minerals in the salt, which precipitate at different stages in the evaporation process.

Recent work has, however, shown that there is a less strenuous way to extract chunks of salt from a rock surface. This involves the use of wooden troughs, as described in the next section. Experimental work by Dan Buzea from the National Museum of the Eastern Carpathians in Sf. Gheorghe (south-east Transylvania) has shown that by letting fresh water drip from a perforated trough onto a rock salt surface for some hours, depressions where the salt has dissolved are produced (Buzea 2010; 2013) (Figure 5A). A series of such depressions can then be used to break up an entire rock surface. Buzea's experiments have shown that it is possible to collect up 50 kg of rock in 30 minutes by this method (Buzea 2018) (Figure 5B). This figure does not, of course, take account of the work involved in preparing the wooden trough and associated channelling to bring water to the site;

(a)



(b)

Figure 5 A. Depressions in rock salt produced by letting fresh water drip onto the rock surface. B. Implements used in the reconstruction of salt production by Dan Buzea.

Photos: Dan Buzea/Valeriu Cavruc.

but it is nevertheless an impressive total, for relatively little effort in the gathering process. It is interesting though that this technique is so far only known from a relatively limited area, central and northern Transylvania and the Maramureş (including the adjacent part of Ukraine, formerly known as the northern Maramureş). It would not be surprising to find it in neighbouring Moldavia, or indeed in south-east Poland, but so far this has not happened.

It is not known what happened to the chunks of rock salt that could have been recovered in this way, but in the absence of any evidence that they were ground down to produce usable salt, it is probable that, just as at Hallstatt, the rock was dissolved in pools and evaporated to produce crystals in a purer form.

The Trough Technique

The use of large wooden troughs, supplied by channelled wooden poles bringing water to them, has been shown by recent work to have been a particularly important technique for salt production in one particular part of Europe. This was first noted in what is today Ukraine in the nineteenth century (Preisig 1877), but remained a curiosity until another similar object turned up in a salt-mining pit at Valea Florilor in Transylvania in the 1930s (Maxim 1971). These and other similar finds were finally recognised for what they were when fieldwork in northern Transylvania at the site of Băile Figa near Beclean began in 2005 (Harding & Kavruk 2013). Since then a whole series of troughs has been discovered at Figa (Figure 6): seven at the time of writing, and more from other sites in the area. They were clearly part of an established method of producing salt in the area of present-day Romania, along with the Ukrainian find north of the river Tisza.[2]

All the finds come from salt extraction pits and mines or salty streams. At Figa, the only site to have been scientifically excavated, the troughs lie in or beside the stream bed, close to the rock salt which lies a short distance below. In one area of the site, a series of other installations were found, notably a tapering well-like feature constructed of wattle with a narrow and deep ditch dug in the rock salt through the middle of its base, a straight fence made of upright planks, split troughs, channelled pieces and shovels stuck in the mud down to the rock salt; a roundish wattle fence enclosing the well; a corridor made of two parallel lines of massive poles; a sort of floor made of massive timbers and lying on the rock salt around the well base; as well as five complete troughs and numerous implements of wood and stone (Figure 7). In other areas there are wattle fences forming oval or round constructions, presumed to be for storing concentrated brine, and many other installations of uncertain purpose.

[2] Adjacent areas of south-east Poland and western Ukraine might also have utilised this technique, but in the absence of detailed fieldwork this remains speculative.