Geology of the Salt Field Rheinfelden-Riburg, Switzerland

Lukas Hauber

Vereinigte Schweizerische Rheinsalinen A.G.
CH-4133 Pratteln 4, Schweizerhalle, Switzerland

ABSTRACT

The Muschelkalk (middle Triassic) east of Basel (Switzerland) contains salt deposits, but the center of these Muschelkalk deposits lies in northern Germany and only a restricted extension leads southward to the region of the Main River and Württemberg in Germany and to Lorraine (France) and Switzerland. In Switzerland, the deposit shows features of a long but relatively narrow, flat and shallow gulf which is filled with evaporitic sediments. Within this gulf, the salt deposits are separated into individual basins, each with its own tectonic history and specific framework. One of these deposits is the Rheinfelden-Riburg salt field located 20 km east of Basel. Extensive drilling provides a good knowledge of the extent of this salt field. It has the shape of a widespread triangle, two sides of which are formed by faults. Only the northern limit coincides with an edge caused by subrosional activity without tectonic interference. The thickness of the salt increases over a short distance from north to south by nearly 100 m where it ends abruptly at a fault zone. There is good evidence that these faults were active during the deposition of the salt. They belong to a system of Hercynian faults in the nearby Black Forest of Germany and have been reactivated in Tertiary times during the subsidence of the Rhein Graben. The stratigraphy of the Muschelkalk is discussed together with the formation and configuration of the Rheinfelden-Riburg salt deposit.

ZUSAMMENFASSUNG

Das Salzvorkommen von Rheinfelden-Riburg, ca. 20 km E von Basel, gehört zum Muschelkalk (mittl. Trias), der Salz in grosser Verbreitung aufweist. Das Zentrum des Muschelkalkmeeres liegt in Norddeutschland, ein Golf erstreckte sich zwischen Pariser Becken und böhmisch-vindelizischer Masse gegen S. In diesem sind die Salzvorkommen von Lothringen, Württemberg und der Schweiz gelegen. Trotz dieser Zugehörigkeit zu einem grossen Salinar zeigt aber das Salzlager von Rheinfelden-Riburg individuelle Züge und ein eigenständiges geologisches Verhalten.

Durch zahlreiche Bohrungen ist seine Ausdehnung recht genau bekannt. Es bildet ein offenes Dreieck. Auf zwei Seiten ist es von Bruchstrukturen begrenzt, einzig im N endet das Salzlager an einem nicht tektonisch beeinflussten Subrosionsrand. Die Salzmächtigkeiten nehmen von N nach S rasch zu und erreichen knapp 100 m. Das Salzlager endet abrupt an einer Verwerfung. Es kann gezeigt werden, dass die Brüche während der Entstehung des Salzlagers aktiv gewesen sind. Sie können späten Phasen der variszischen Gebirgsbildung im Schwarzwald zugeordnet werden und sind im Tertiär im Zusammenhang mit dem Einsinken des Rheingrabens reaktiviert worden.

Im weiteren werden die stratigraphischen Verhältnisse, die Ausbildung des Salzlagers und seine Gliederung in Zyklen beschrieben.

INTRODUCTION

The first marine ingression into southern Germany, Switzerland and eastern France (Lorraine and Jura) after the Variscan orogeny took place in the middle Triassic (= Muschelkalk). The lower Triassic shows the features of erosion of the Variscan mountains; the Buntsandstein (mainly red sandstones) was deposited from south to north into a trough, whose center lays within the lowlands of northern Germany (Wurster, 1968). The marine transgression filled a relatively narrow gulf between continents in the west (Basin of Paris–Ardennes) and in the east (Bohemian massiv, Vindelician sill). In the upper Muschelkalk this transgression reached the Provence (Tethys) in southern France (Ricour, 1963; Lemcke, 1970, 1973).

During the middle Muschelkalk evaporitic sediments were deposited in the main basin as well as in the narrow gulf. Figure 1 shows the known salt occurrences in southern Germany, Switzerland and neighbouring France in saltworks and saltmines. Though there is no connection from one salt field to another, there are several features in common. These data might lead to the idea that there has been one common original salt layer of large extent and that the separation into several independent salt fields is due to a subsequent dissolution or subrosion of large amounts of salt. On the other hand there is also the possibility of originally separated salt fields, which have been deposited within the same time range and under the same geological conditions. In other words, within the previously mentioned north-south gulf there existed several restricted basins where the salt preferably could be deposited or protected from later erosion.

The salt fields in the Rhine valley east of Basel are well known due to intensive drilling. It might be of interest to compare this information with that from other Triassic salt occurrencies. The salt field of Schweizerhalle-Zinggibrunn has been described before (Hauber, 1971), therefore the geology of another salt field, Rheinfelden-Riburg, has been chosen as a basis for discussing the question of the genesis of the salt.

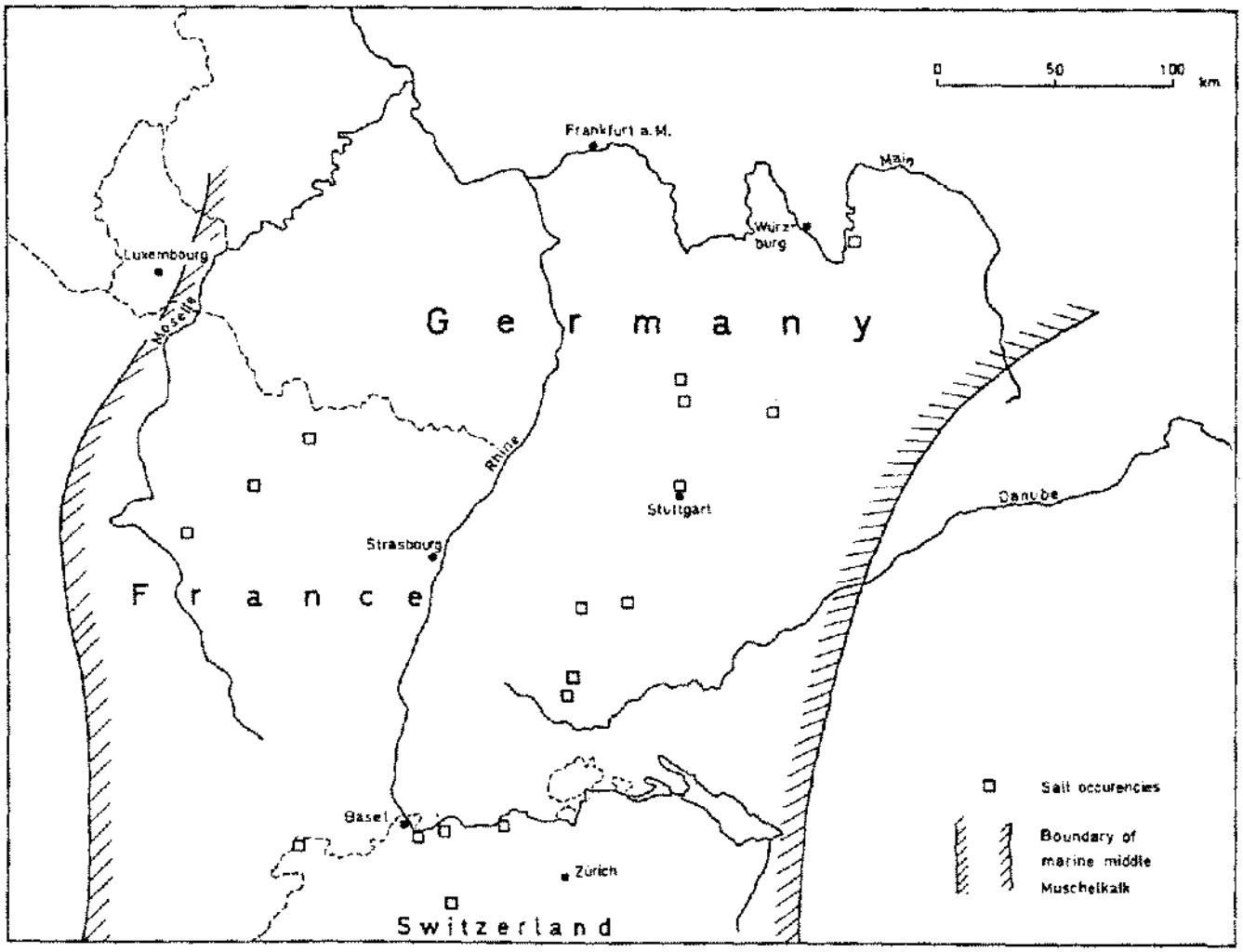

Figure 1. Distribution of salt in the Middle Muschelkalk in Baden-Württemberg, Switzerland and neighboring France.

The first salt in the Rhine valley east of Basel was found in 1836 by Carl Christian Friedrich Glenck (1779–1845) at Schweizerhalle with his seventeenth borehole in the search of salt. By 1837 the saltworks of Schweizerhalle were in operation. By 1848 three more had been built: Kaiseraugst, Rheinfelden and Riburg. Today Schweizerhalle and Riburg are still in operation and are equipped with highly advanced thermo-compression evaporators (capacity: 200,000 t/year each).

GENERAL GEOLOGIC SETTING

The Triassic in the Rhine valley east of Basel belongs to the sedimentary cover of the Variscan basement of the Black Forest (Fig. 2). The sediments dip gently southward, generally at 5–10°. The thickness of the overburden sediments above the salt, increases with distance from the Rhine to the south.

The most striking tectonic feature of the region between Basel and Säckingen is the presence of a great number of faults, most of them in a NNE–SSW direction, but also in the NW–SE direction. They belong to the Rhinegraben system, which is lower Tertiary in age (Fig. 2). The Rhinegraben is a riftvalley, which separates Black Forest and Vosges. In this system the NW–SE Hercynian direction seems to be strange. Indeed, as will be shown, these faults originate from the Variscan orogeny, persisted into Triassic times and have been reactivated during the growth of the rift valley system in the Tertiary. The examination and description of the Rheinfelden-Riburg salt field will provide some additional data and information on this statement.

STRATIGRAPHY

The stratigraphy of the Triassic sediments of Rheinfelden-Riburg is the same as in Schweizerhalle (Hauber,

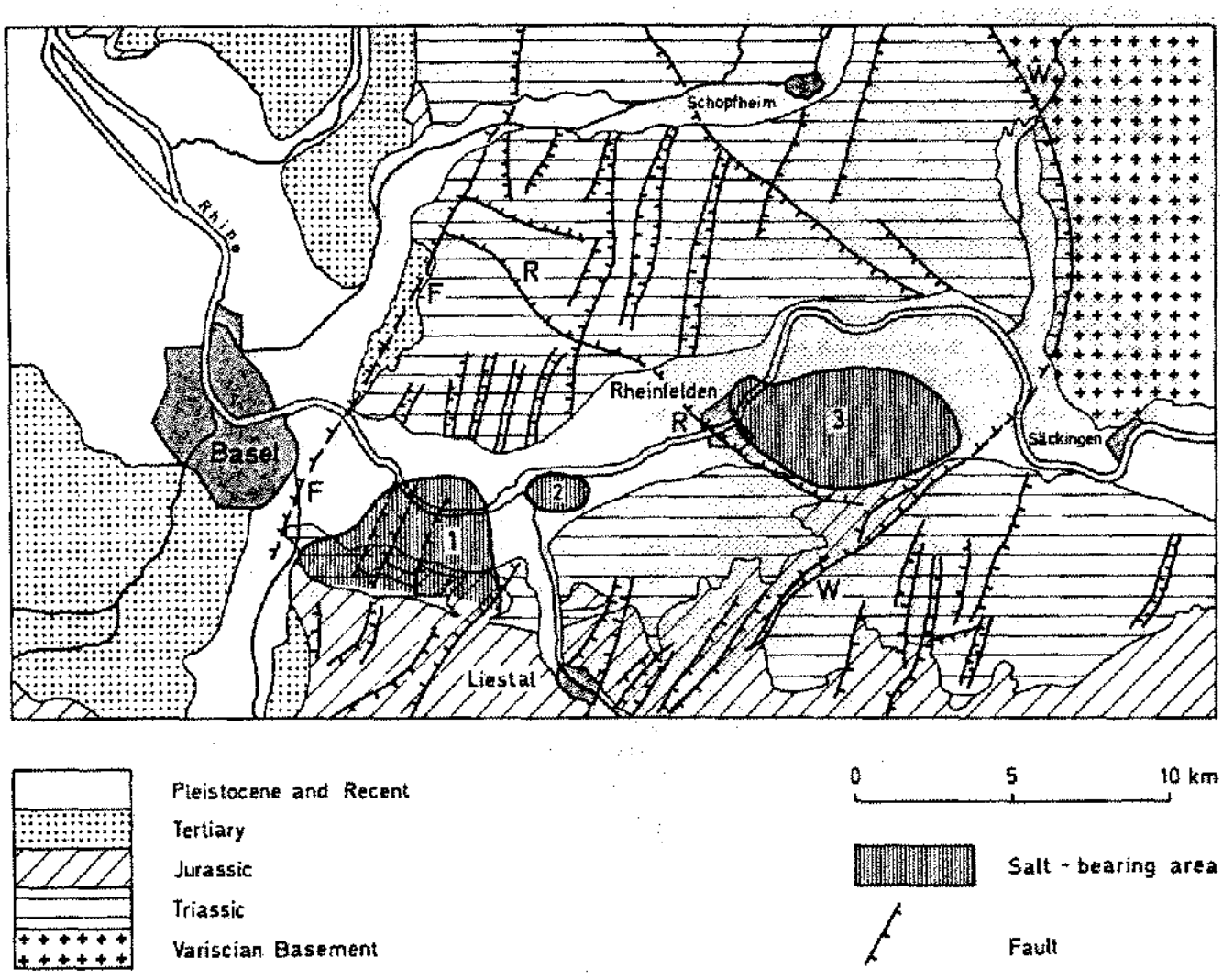

Figure 2. Geological position of the salt fields in the Rhine valley east of Basel. *1*, Schweizerhalle; *2*, Kaiseraugst; *3*, Rheinfelden-Riburg; F. Flexure of the Rhine graben; R. Degerfelden-Rheinfelden fault; W. Kandern-Wehratal-Zeiningen fault.

1971). Table 1 shows the stratigraphy of the Muschelkalk including the average thickness of the various formations and layers.

Figure 3 shows typical stratigraphic sections of some fully-cored wells in Riburg and illustrates the lithology and the regularity of the thickness of the different members. The abnormal thickness of the upper Sulfatzone in well 6 is probably due to repetition by a fault, but the details are not well known for this old well. Wells 6 and 12 have been production wells; the others are exploratory wells. The thickness of the Wellengebirge is given according to Disler, 1914.

THE SALT BED

The publications of Schachl (1952, 1954) show a neat separation of the Muschelkalk salt bed in south Germany into three different layers. Wild (1977) shows that in the center of the salt field at Heilbronn there might even be a forth salt cycle. East of Basel, in the Rhine valley, it is not possible to distinguish the same three or four different cycles, although there are a large number of well profiles available. However, several common features are discernible in the salt layers, so it should be possible to find the same cycles as in Germany.

The typical outlines of the salt bed of the two best known salt regions in Switzerland (Schweizerhalle and Rheinfelden-Riburg) are as follows:

1. Under the salt bed there is normally a thin layer (0.2–0.8 m) of gray clay with nodules or lenses of red salt (= Salzton; Schachl, 1952; Trefzger, 1950).
2. The lower salt bed, in the lower part is a quite pure, granular salt.
3. The lower salt bed, in the middle part is a sequence of salt layers with clay and anhydrite.
4. The lower salt bed, in the upper part is a coarse crystalline salt with some impurities, but only few seams of clay or anhydrite.
5. The "Trennschicht," an anhydrite bed, separates the lower and upper salt, and is up to 10 m thick.
6. The upper salt layer is a coarse crystalline salt with clay and anhydrite impurities.

Extension of the salt field. The extent of Rheinfelden-Riburg is shown on Figures 5–7. The southern limit of the salt is formed by faults, the Rheinfelden fault (R) and the Wehratal fault (W) (Fig. 2). Well 18, south of the Rheinfelden fault, proves that there is no salt there. However, the greatest thickness of salt can be found immediately on the northern side (80–100 m; wells 17, 40, 51). The question, whether the salt in well 18 is primarily lacking or eroded cannot be answered definitely. Note, however, that the upper Sulfatzone and the younger layers show no signs of disturbance due to subrosion or something else which would indicate the former existence of salt. If there had been salt, it could not have been 100 m thick or anything like that. In any case, removal would have to have taken place before the sedimentation of the upper Sulfatzone.

On the northern edge of the salt field there are signs of active subrosion. As is shown in Figures 4 and 5, the top of the salt dips northward from well 47 to 43, which is a remarkable feature considering the regional geology. The underlaying beds on the other hand show reversed dip. In addition to this, cores of well 44 just outside of the salt field show abundant veins of gypsum in the anhydrite of the upper Sulfatzone as well as unconsolidated clay in the position of the missing salt. This proves the existence of subro-

TABLE 1

Stratigraphy of the Muschelkalk (Middle Triassic) in the Region of Rheinfelden-Riburg (Switzerland).

Period	Group	Formation	Member	Lithology	Thickness in m
Triassic	Keuper		Lettenkohle	Dolomite and shale	6–8
	Muschelkalk		Trigonodusdolomit	Dolomite	25–30
		Hauptmuschelkalk	Plattenkalk	Limestone	20–25
			Trochitenkalk		20–25
		Anhydritgruppe	Dolomitzone	Dolomite	15–20
			upper Sulfatzone	Marl and anhydrite	27–45
			Salt Bed	Salt	0–100
			lower Sulfatzone	Dolomitic marl and anhydrite	2–5
		Wellengebirge	Orbicularismergel	Marl with intercalations of anhydrite	8–10
			Wellenkalk	Limestone	25–30
			Wellendolomit	Dolomite	5–8
	Buntsandstein		Röt	Shale and sandstone	7–15

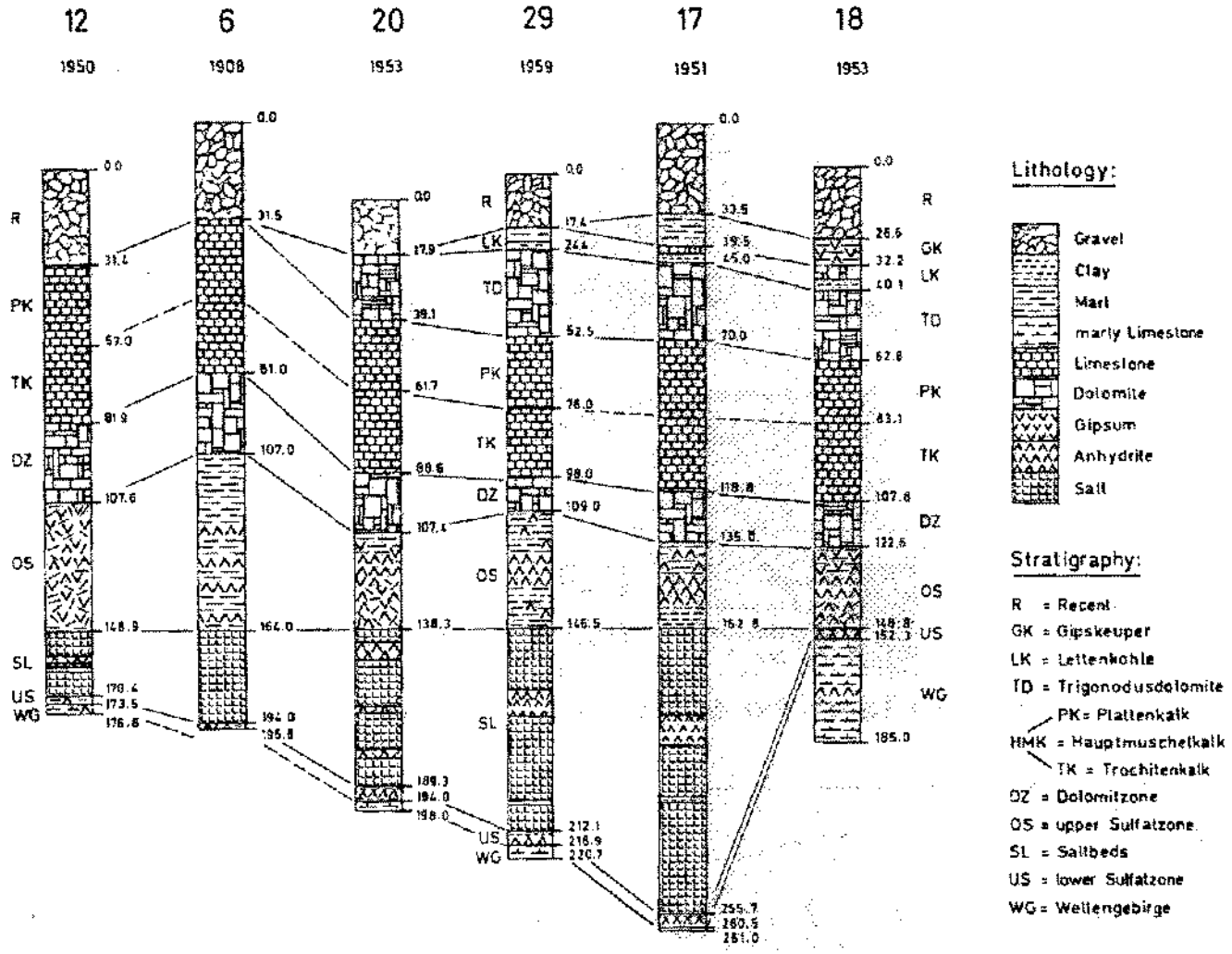

Figure 3. Sections of wells in the Rheinfelden-Riburg salt field (well 6 from Verloop, 1909). Situation see Figs. 5–7.

sion, which became possible due to erosion by the young Rhine river. To the northeast, the salt field wells 15 and 16 do not show these signs of subrosion, and therefore one cannot determine the original edge of the saltbasin.

Genesis

The facts lead us to the following *conjectural picture of the genesis* of the salt field of Rheinfelden-Riburg, which would be in accordance with these observations:

1. There was a strong increase of the thickness of the salt from north to south (Fig. 7).
2. According to the facts mentioned above, the base of the salt dips more to the south than the top; but there is a difference in the strike (see Figs. 5 and 6).
3. The northern boundary of the salt shows the influence of the recent subrosion activity.
4. As the sections in Figure 3 indicate, there are additional salt layers in the southern part of the salt field which coincide with an increase in thickness of the older salt layers.
5. The southern edge of the salt reflects the Rheinfelden- and Wehratal-Zeinigen faults. As Figure 4 shows, the difference in thickness of the Wellengebirge/Sulfatzone-boundary in well 40 and 18 equals as much as 140 m, but for the Sulfatzone/Hauptmuschelkalk-boundary there is only 40 m difference. This difference of about 100 m is nearly equivalent to the thickness of salt in wells 17 or 40.
6. As in Germany, there are indications for the existence of three subsequent cycles, as shown by layers of pure salt alternating with impurities as clay or anhydrite. Very typically the "Trennschicht" (= separating layer) of anhydrite occurs in the upper third of the whole salt bed.

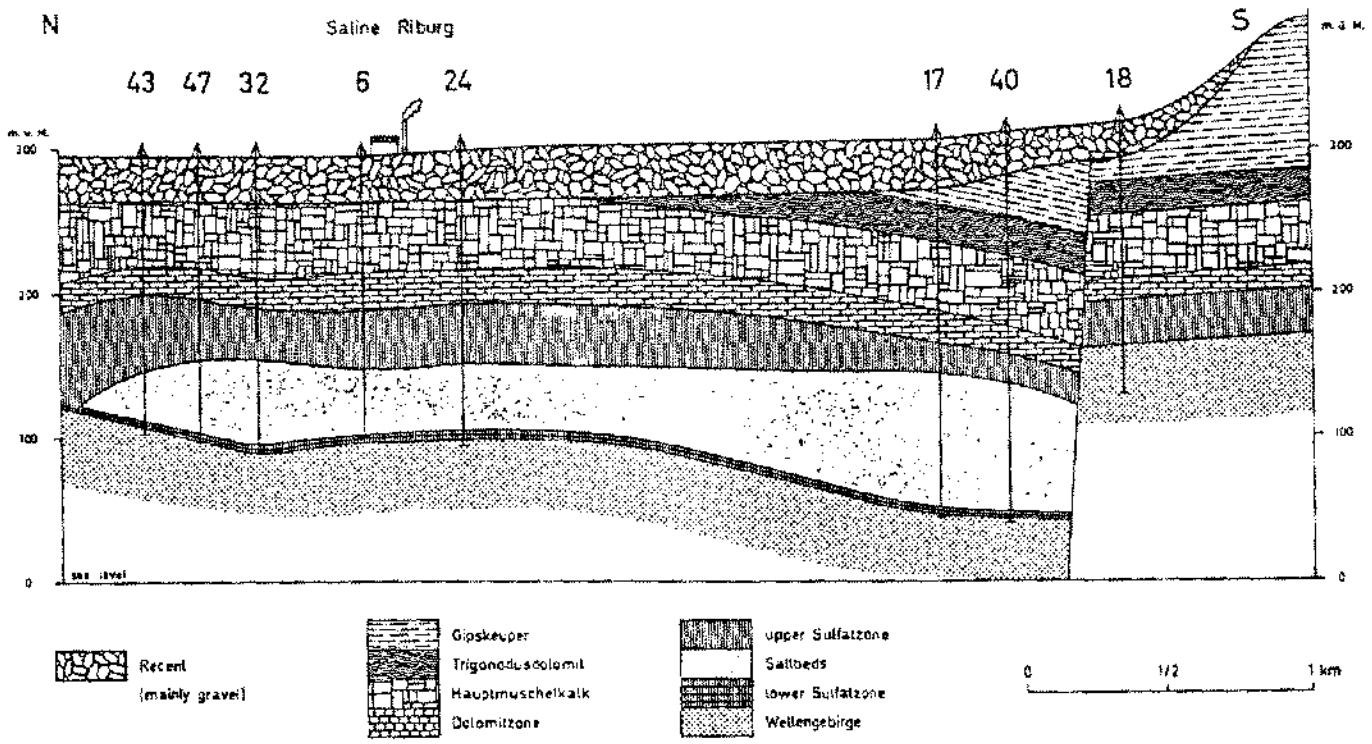

Figure 4. Cross section of the salt field Rheinfelden-Riburg.

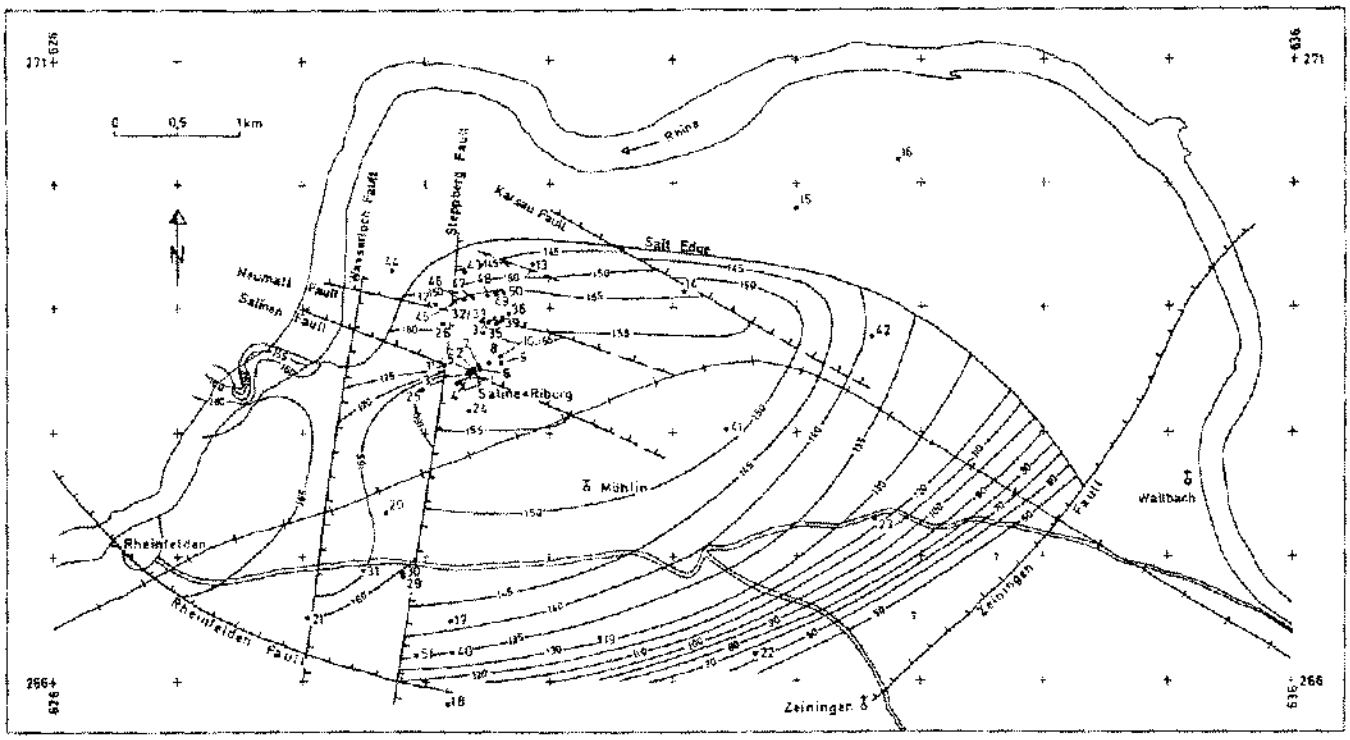

Figure 5. Contours of the top of the salt in the salt field Rheinfelden-Riburg. Contour interval 10 meters.

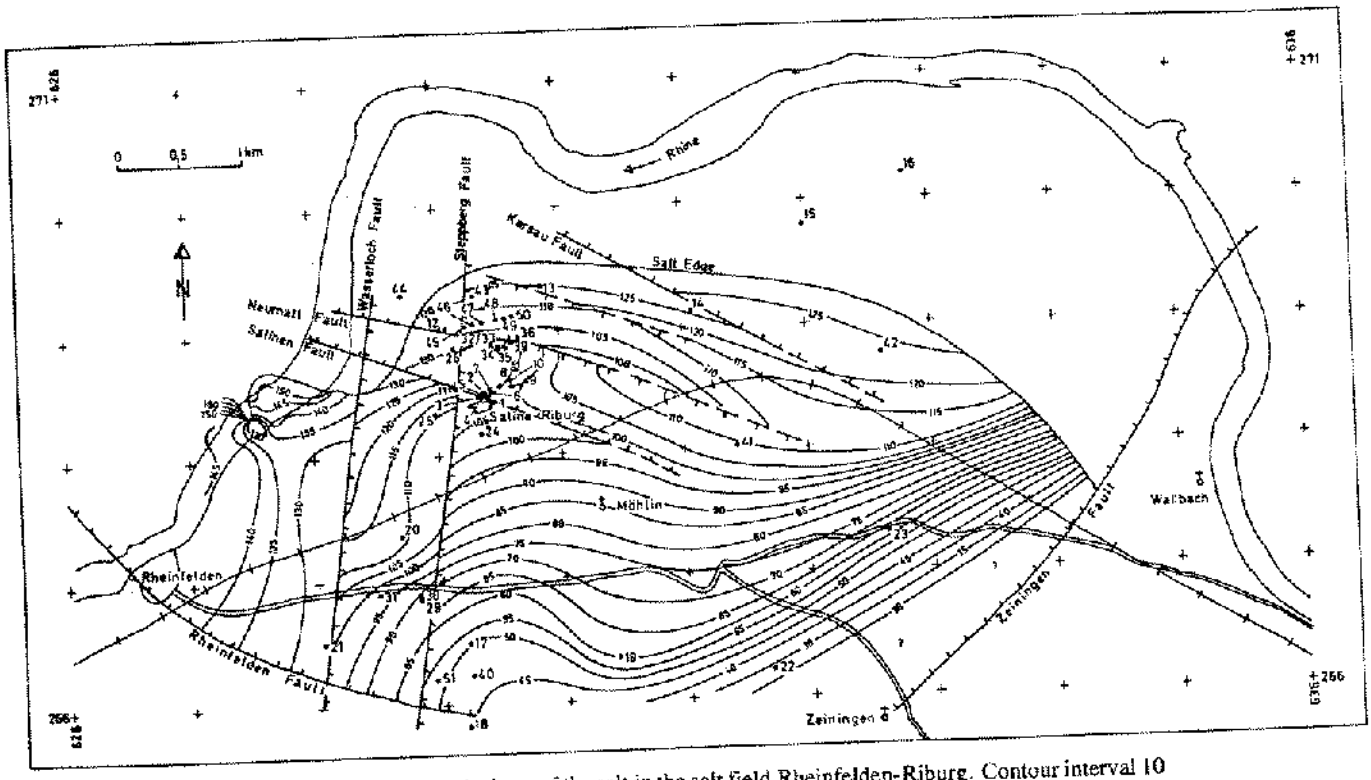

Figure 6. Contours on the base of the salt in the salt field Rheinfelden-Riburg. Contour interval 10 meters.

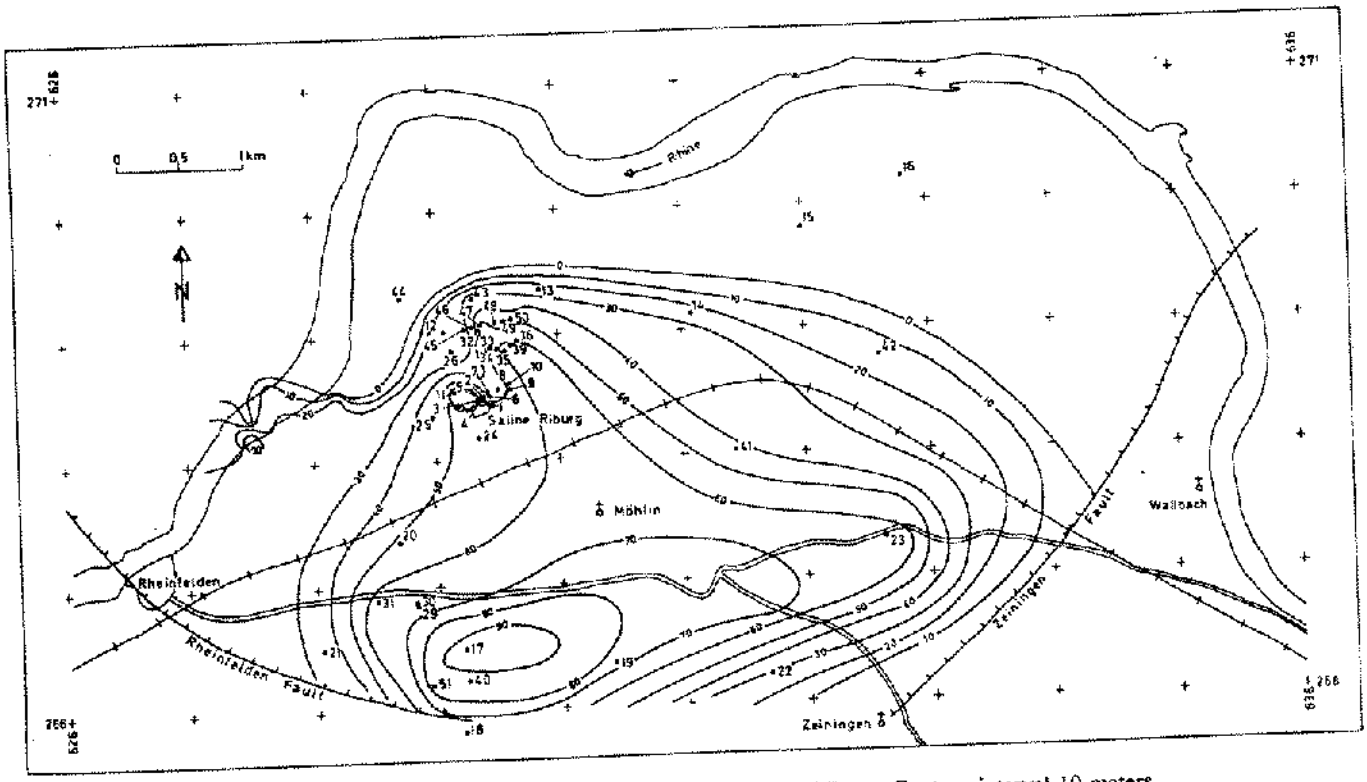

Figure 7. Isopach of the salt in the salt field Rheinfelden-Riburg. Contour interval 10 meters.

Due to these important characteristics of the salt field, it seems probable that there has not been an unique, extended salt basin in the middle Muschelkalk, which reached from Germany into France and Switzerland, but instead that there existed several different restricted basins within the marine trough or gulf where the accumulation of the salt preferentially took place. The extension of such basins could be due to slow movements along old fault structures existing since the Variscan orogenesis (see also Hauber, 1971).

Such an interpretation obviously requires a long period for the genesis of the salt basin. This is in contrast to the conception of quick sedimentation of salt. But because there are different cycles with salt beds, it is most likely that these beds were not deposited within one short period, but during several periods. In between these periods of salt deposition there was time for dissolution and recrystallization of the salt and a certain concentration of the impurities.

Following this model, it would be possible that the salt originally had a larger extent than today and was also present on the other side of the Rheinfelden fault. In such a case, due to dissolution in the periods between the salt cycles, the distribution of the salt was reduced to the central part of the local salt basin. As mentioned above, three cycles of salt can be observed in Riburg. The uppermost, i.e. youngest, can be found only in the center of the basin. Also the thickness of the cycles decreases towards the edges of the basin. This is in line with the assumption of a "restricted" salt basin, as proposed by Trusheim (1971).

COMPARISON OF SWITZERLAND–WÜRTTEMBERG

Schachl (1974) gave a detailed and precise description of the Muschelkalk salt in Württemberg comprising the sequence of Lower Salt–Bändersalz–Upper Salt. Until now no such sequence could be found in the Rhine valley east of Basel. But the sections in a great number of wells allow one to assume the existence of three cycles in the Salt Layer, too. Thus, there would be a good correspondence with the Württemberg section. In both cases, the thickness of the salt is greatest in the center (Dellwig, 1966; Wild, 1965). In the center of the Heilbronn salt field, there is even a fourth cycle (Wild, 1977) which as yet has not been found in Switzerland, but which exists in the main basin of north Germany (Trusheim, 1971). As in Switzerland, the underlaying formations show a stronger undulation than the overlying formations. The thickness of the salt ranges within the same limits in Switzerland as in Württemberg. These common features prove that the salt of both regions might have been formed under the same general geological conditions, but in detail there have been differences, which show that each area has its own history.

DISCUSSION

G. Lüttig:

Question. The river Rhine is flowing round the salt deposit of Rheinfelden in a bow convex to the north. Is there any correspondence to an uplift of the salt during Quaternary times, so that the river could have been guided round the salt deposit?

Answer. No, we see some connections of the convex bow of the Rhine river to the north with the complex tectonic pattern of the Rhinegraben-rift valley. The activity continues until recent times with an uplift of the Black Forest and the Vosges and a descedence or inclination of some parts of the graben. Such phenomena exist also in regions, where no salt is known.

REFERENCES

Dellwig, L.F. 1966. The Muschelkalk Salt at Heilbronn, Germany. Second Symp. on Salt, Cleveland Ohio. 1: 328–334.

Disler, C. 1914. Stratigraphie des Rothegenden und der Trias beiderseits des Rheins zwischen Rheinfelden und Augst. Verh. natf. Ges. Basel 25: 1–96.

Hauber, L. 1971. Zur Geologie des Salzfeldes Schweizerhalle-Zinggibrunn (Kt. Baselland). Eclogae geol. Helv. 64(1): 163–183.

Lemcke, K. 1970. Epirogenetische Tendenzen im Untergrund und in der Füllung des Molassebeckens nördlich der Alpen. Bull. Ver. schweiz. Petrol. Geol. u. Ing. 37(91): 25–34.

———. 1973. Zur nachpermischen Geschichte des nördlichen Alpenvorlandes. Geologica bavar. 69: 5–48.

Ricour, J. 1963. Esquisse paléogéographique de la France aux temps triasiques. Mém. Bur. Rech. géol. min. 15: 715–734.

Schachl, E. 1952. Das Muschelkalksalz in Kochendorf, Heilbronn und Stetten/Hohenzollern. Jber. Mitt. oberrh. geol. Ver. NF 34.

———. 1954. Das Muschelkalksalz in Südwestdeutschland. Neues Jb. geol. paläont. Abh. 98: 309–394.

Trefzger, E.F. 1950. Die Steinsalzlagerstätte von Rheinfelden (Baden). Stratigraphie, Solung und Senkung. Jber. Mitt. oberrh. geol. Ver. NF 32: 95–127.

Trusheim, F. 1971. Zur Bildung der Salzlager im Rotliegenden und Mesozoikum Mitteleuropas. Beitr. geol. Jb. 112: 1–51.

Verloop, J.H. 1909. Die Salzlager der Nordschweiz. Diss. Univ. Basel, 1–34.

Wild, H. 1965. Ablaugungserscheinungen (Subrosion) am Salzlager des Mitteleren Muschelkalkes und Schichtlagerung unter und über dem Salz im Heilbronner Raum. Jh. geol. Landesamt Baden-Württemberg 7: 603–610.

———. 1973. Neue Erkenntnisse über Genese und Lagerung des Salzes in Mitteleren Muschelkalk in Süddeutschland. Jber. Mitt. oberrh. geol. Ver. NF 55: 95–132.

———. 1977. Salzlagerstätten des Mittleren Muschelkalks. Jber. Mitt. oberrh. geol. Ver. NF 59: 13–17.

Wurster, P. 1968. Paläogeographie der deutschen Trias und die paläogeographische Orientierung der Lettenkohle in Südwestdeutschland. Eclogae geol. Helv. 61(1): 157–166.