Annales de la Société Géologique de Belgique, T. 106 - 1983, pp. 103 - 109 Juin 1983

THE LUXEMBURG SANDSTONE FORMATION (LIAS), A TIDE-CONTROLLED DELTAIC DEPOSIT [1]

by

G. MERTENS, E.-D. SPIES & T. TEYSSEN [2]

(5 figures)

RESUME.- La formation du Grès de Luxembourg a été déposée dans un golfe marginal du Bassin de Paris comme un delta sableux et diachronic. Les paléocourants indiquent un transport de matériaux sableux depuis la zone de dépression de l'Eifel. Une nouvelle investigation des structures sédimentaires démontre une accumulation sous l'effet de courants bipolaires. Ce résultat est opposé aux opinions précédentes. On peut distinguer plusieurs faciès sédimentaires correspondant à différents milieux de dépôt. A partir de l'analyse des structures sédimentaires, on peut conclure à un régime mésotidal des marées et à des vitesses de courants de marées relativement hautes. Le déplacement latéral du delta a été contrôlé par la tectonique.

ABSTRACT.- The Liassic Luxemburg Sandstone Formation was deposited within a marginal gulf of the Paris Basin as a diachronous sandy delta. Palaeocurrents indicate the transport of material from the Eifel Depression. Reinvestigation of the cross-stratification showed a general bipolar directional distribution in contrast to results of previous workers. Several facies types can be distinguished and these are interpreted as reflecting different depositional environments. Examination of the sedimentary structures led to the conclusion of a mesotidal control on the sedimentation, causing relatively high palaeotidal flow velocities. The lateral shifting of the deltaic depocenter was tectonically controlled.

1.- INTRODUCTION

Within the area of the Liassic gulf of Luxemburg (fig. 1) the calcareous sediments of the Hettangian and the Sinemurian of the Paris Basin are replaced by a sandy facies tongue, the Luxemburg Sandstone Formation. The thickness distribution of the sand facies as well as its relatively uniform development led to its interpretation as a deltaic sand body (Levallois, 1865 ; Muller, Preugschrat & Schreck, 1976 ; Muller, 1980). The diachronous Luxemburg Sandstone develops with a gradual coarsening upward from the basal Marls of Jamoigne. The Marls and Limestones of Strassen overly the eroded top of the Luxemburg Sandstone Formation. The depositional history of the formation has been discussed controversially. This study gives a new interpretation of the sedimentary facies and of the external control of deposition.

2.- SEDIMENTARY FACIES

The Luxemburg Sandstone Formation is characterized by fine to medium grained, very well sorted, cross-stratified sandstones with a calcareous matrix. The sands have a high compositional maturity and low amounts of potassium feldspar. Plagioclase has nearly totally been destroyed. The heavy mineral spectrum is a stable mineral association of zircon, tourmaline, rutile, garnet, epidote and staurolite (Schreck, 1976 ; Mertens, 1982 ; Spies, 1982).

The sedimentary structures have been used to identify different facies types :

SAND WAVE FACIES

Well developed sand waves (sensu Allen, 1980) reflecting tidal influence can be found in the Luxemburg Sandstone Formation (fig. 2). The best outcrop of this facies lies to the NE of Luxemburg city along the road N1 to the airport. Tidal bundles (Boersma, 1969), with well developed bottomsets and subordinate

1 *Manuscrit reçu le 16 février 1983.*

2 *Geologisches Institut, Universität Bonn, Nussallee 8, 5300 Bonn 1, Germany.*

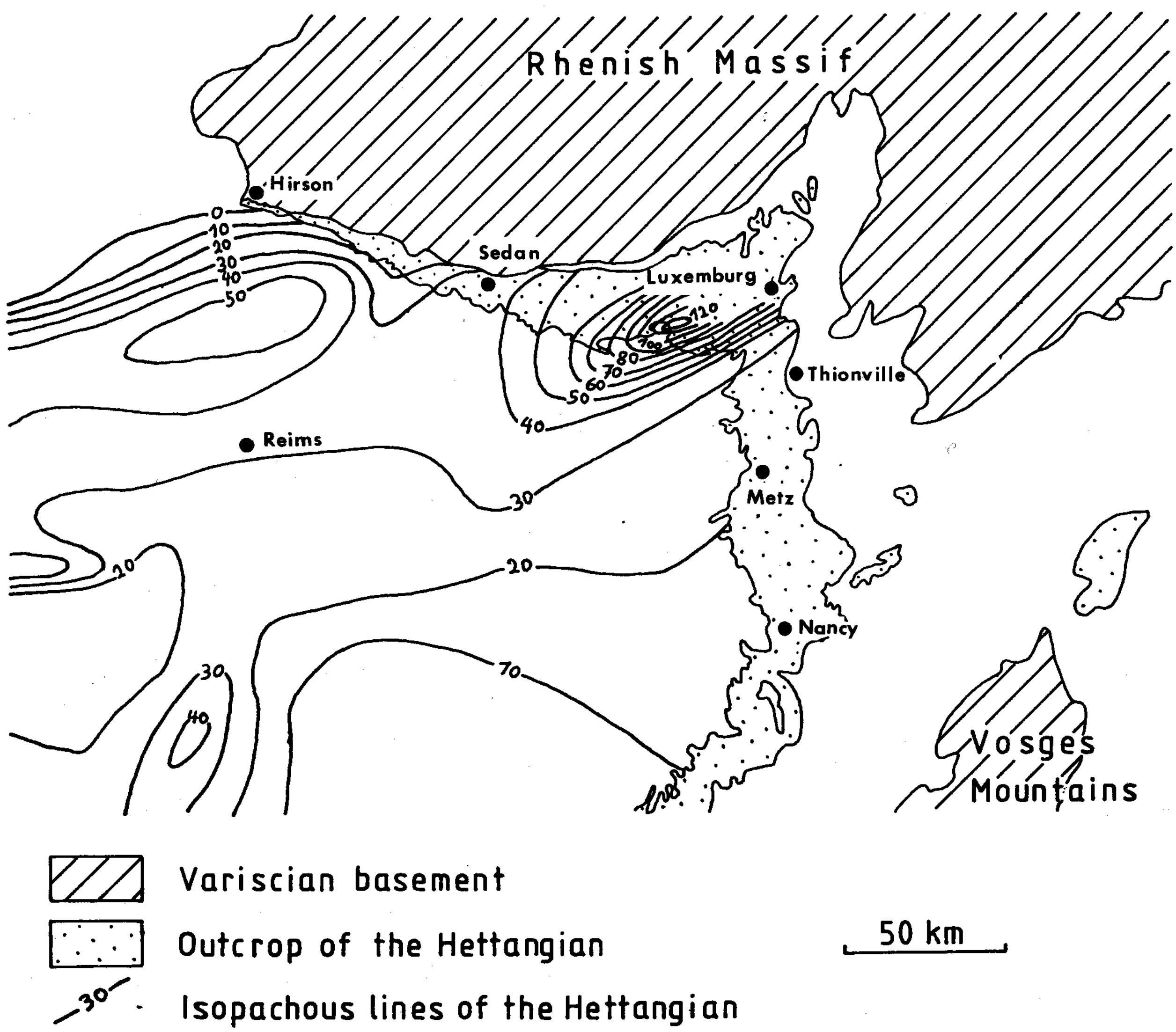

Figure 1
Paleogeographical map of the Hettangian at the northeastern margin of the Paris Basin after Debrand-Passard (1980).

current reactivation surfaces, together with the very well sorted sands, give evidence for a tidal origin. The internal structure of the sand waves is comparable to the features described by Visser (1980) and Homewood & Allen (1981). Reactivation by subordinate currents is comparable to that of class B of Mowbray & Visser (1982, fig. 2). The sedimentary sequence is built up by sand waves having overridden each other, probably during lateral accumulation within tidal channels. These sand waves, together with large scale low angle cross-stratification which is abundant within the whole outcrop zone of the formation, may indicate the existence of tidal channels. Calculation of tidal velocities from the sand waves (Teyssen, 1983) leads to peak velocities from 0.8 up to more than 1.5 knots (0.4 - 0.75 m/sec) which in comparison with recent tidal environments fits well to channelized flow.

Sand wave heights of up to 1 m, and height of large scale tabular cross-sets up to 2 m, suggest a mesotidal regime. Bundle thicknesses display "thick-thin" alternations due to diurnal inequalities of tides (Visser & De Boer, 1982) and indicate a semidiurnal tidal system. The occurrence of coupled mud layers in some sand waves in the outcrop in the NE of Luxemburg city also gives evidence of a tidal environment, a sub-

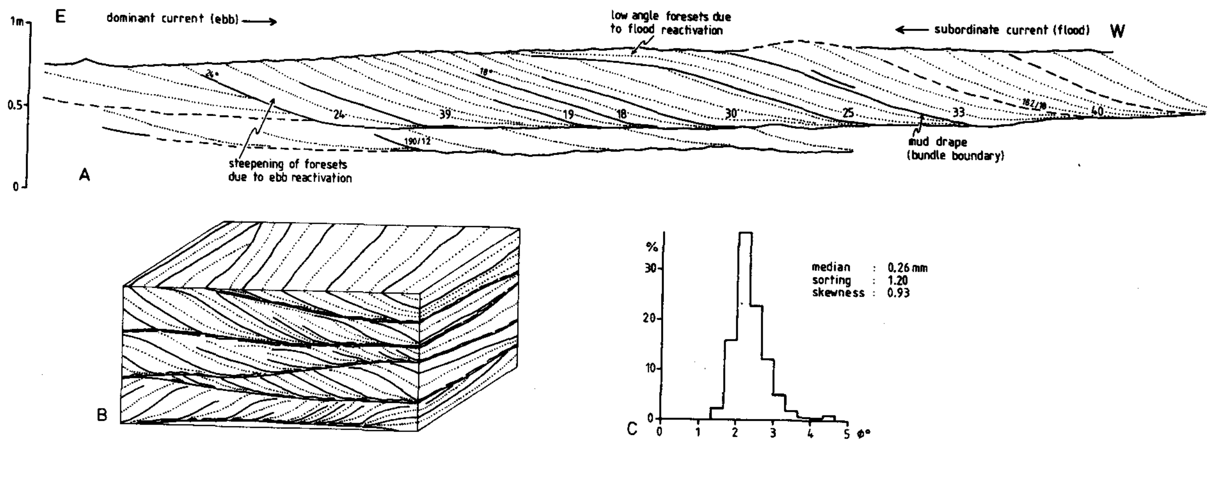

Figure 2

Sand wave facies of the Luxemburg Sandstone Formation ;

A) drawing of a sand wave taken at the road N1 NE of Luxemburg city, about 1 km before the deviation to the airport, solid lines : mud drapes, dotted lines : sandy foresets, figures indicate thickness of the bundles.

B) sketch of the facies : the sedimentary facies is built up by sand waves overriding each other.

C) Histogram of grain size distribution of the sand wave of A).

tidal environment seems to be most probably.

SHOAL FACIES

Small scale through cross-stratification and laminated sands are interpreted as interchannel shoal deposits. Two subfacies can be determined :

Subfacies I is characterized by an interfingering of small to medium scale, mostly trough cross-stratified sets (fig. 3A). Current directions indicate a bipolar system in nearly every case. Our investigations led to the conclusion that Bintz & Muller (1965) measured mainly the cross-stratification due to the dominant stream, neglecting the sets to the opposite direction in most cases. Fig. 4 gives a cumulative diagram of cross-bedding foreset directions of the region south of Mersch. A bipolar directional distribution with ebb currents to the south and flood currents to the northeast supports the assumption of a tidal control on the sedimentation. The bipolar distributions measured by Bintz & Muller (1965) and Berners (1981) corroborate these tidal directions.

Subfacies II is characterized by a rhythmical alternation of small to medium scale, low angle tabular cross-sets and laminated sands. The cross-stratification is unidirectional in most cases. The calculated strength of tidal currents in relation to the grain size of the laminar sands suggests deposition as upper flow regime plane beds (cf. Southard, 1971). Abundance of water escape structures in this subfacies II (for example in the Müllertal region in the SW of Echternach) also show high sediment transport rates and is in accordance with the assumption of general high flow velocities. The rhythmical change between low angle dunes and upper flow regime plane beds is interpreted as reflecting tidal induced changes of flow velocities above shoals with a very moderate relief of the sediment--water interface.

CONGLOMERATES

Conglomeratic horizons are intercalated within the sandy sequence. The conglomerates cover areas of up to 100 km^2. Bed thickness ranges from 30 to 70 cm. The conglomerates are rich in shells. The pebbles are well rounded, they have diameters of up to 7 cm and are composed of quartz, flint, siltstone, limestone and silicified limestone, and sandstone (Andrzejewski, 1981 ; Schreck, 1976). The sandstone pebbles prove intraformational reworking of the Luxemburg sandstone. They often contain echinoderms which are typical within sands at the top of the formation and at the top of coarsening upward sequences (cycles) of the formation. Thus deposition of the conglomerates indicate intraformational reworking in proximal parts of the delta in connection with a lateral shifting of

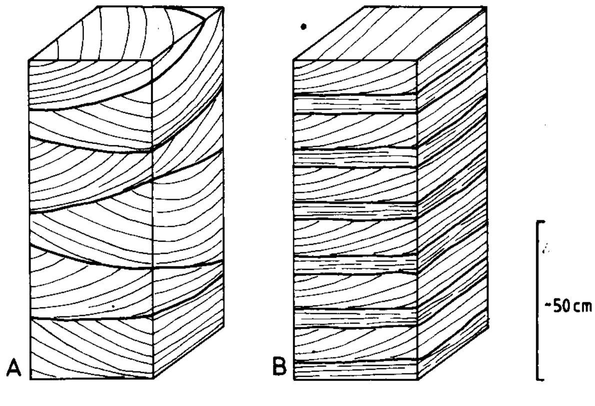

Figure 3
Sketch drawing of the sedimentary structures of the shoal facies, only approximate scale.
A) subfacies I, bipolar trough cross-bedding.
B) subfacies II, alternation of unidirectional cross-stratification and upper flow regime plane beds, compere text.

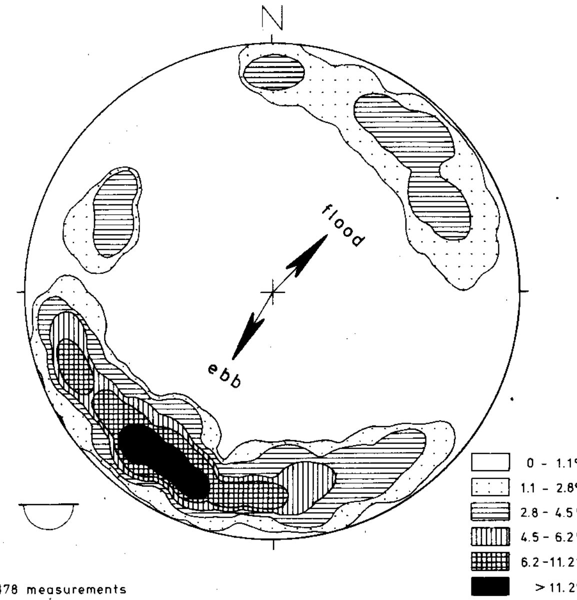

Figure 4
Cumulative diagram of the cross-bedding azimuths and dip angles of the region south of Mersch, for position of measurement sites compare fig. 5. Note the well differentiated ebb and flood directions. The density distribution of both ebb and flood cross-sets reflects a superimposition of directional variation with foreset directions due to trough geometry of cross-sets.

the sandstone deposition (fig. 5, compare also Muller, 1980). Cross-bedding of the conglomerates indicates a high energy regime. In the western part of the outcrop zone south of Redange densely packed conglomerates have been found which after Gervais (pers. comm.) might be interpreted as washout products of pebble bearing sands and as channel lag deposits. The origin of some quartz and silicified limestone pebbles remains uncertain. Pebbles of the same type are abundant within the Rhaetian of Luxemburg (Antun, 1953; Mertens, 1982 ; Spies, 1982) and may be derived from there. But Carboniferous (Andrzejewski, 1981), Permian, and Lower and Middle Triassic source rocks have also to be taken into account.

OOID FACIES

The facies at the top of the Luxemburg Sandstone Formation is characterized by sandstone pebbles due to intraformational reworking, sometimes with bivalve borings, by crinoid detritus and by calcareous ooids (30 - 40 vol o/o). The amount of clastic terrigenous material decreases sharply. Lucius (1948) reports densely packed bivalve shells together with bivalve borings and pool structures from southern Luxemburg. The ooids have diameters between 0.3 and 0.4 mm and are well sorted. 60 o/o of the cores are quartz grains, 40 o/o are bioclasts. The thickness of concentric layers is inverse proportional to the diameter of the core, thus representing hydrodynamic control of ooid growth. Well preservation of the ooids and well sorting indicate lack of major mechanical transport, so that the sites of origin and deposition coincide. The maximal values of concentric ooid diameters allow calculation of flow velocities at 100 cm above the bed of about 2 knots (1 m/sec) (Heller *et al.*, 1980). This is in accordance with a small to medium scale cross-stratification of the sediments of this facies type.

The top of the ooid facies is the so-called "surface taraudée" (Lucius, 1948). This hardground is diachronous and represents the reworking of the locally preserved uppermost distributive cycle of sandstone deposition. Since the formation is built up by deposition of successive coarsening upward sands leading to a conglomeratic horizon with reworking, the "surface taraudée" corresponds to some extent with the conglomerates. On the other hand the "surface taraudée" represents the locally final reworking due to filling up of the basin and shallowing of water depth in connection with the lateral shift of the Luxemburg Sandstone facies.

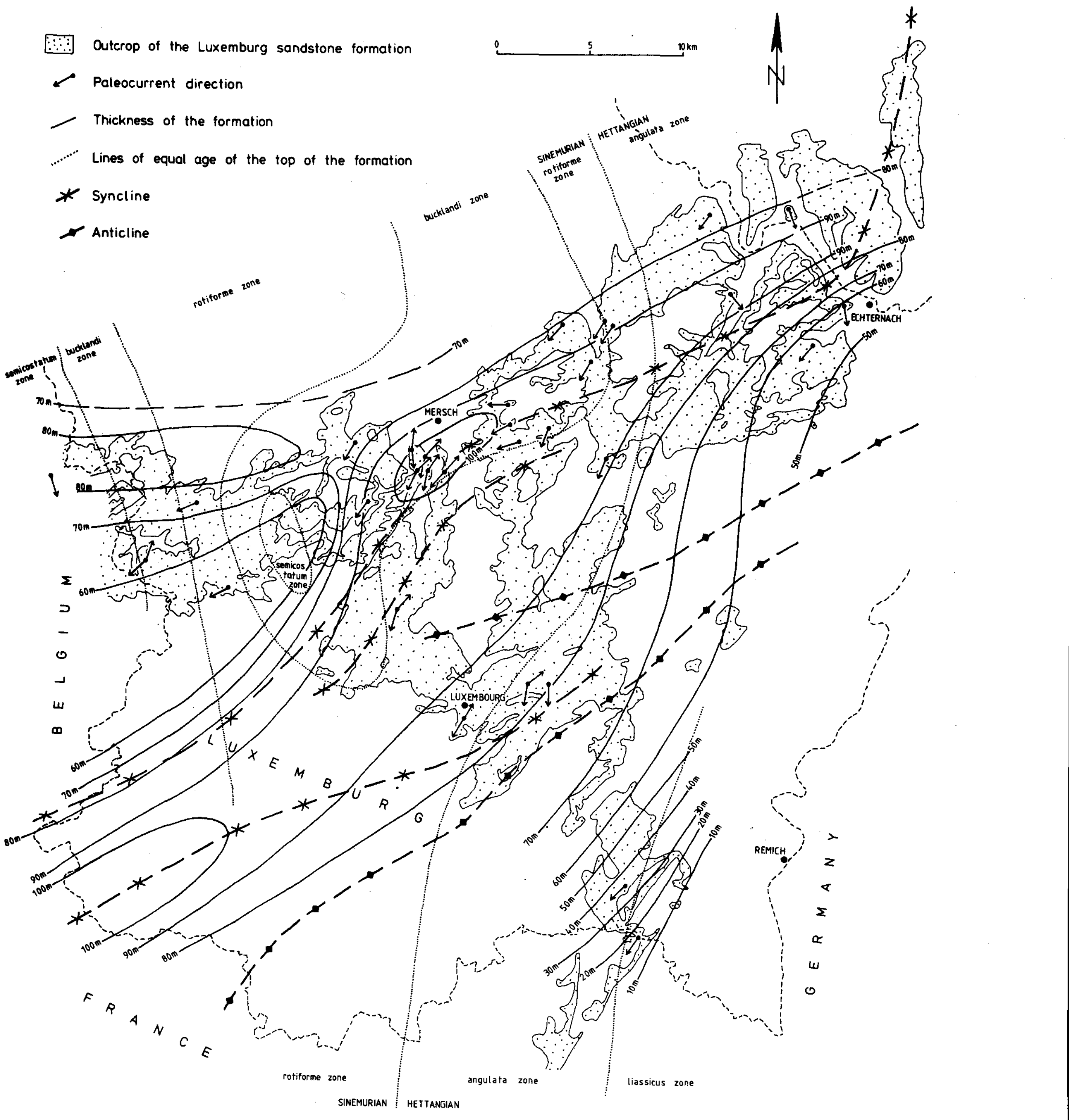

Figure 5

Map of paleocurrent directions of the Luxemburg Sandstone, directions after Bintz & Muller (1965), Schreck (1976), Heilmann (1979), Andrzejewski (1981) and own measurements (bipolar measurement sites south of Mersch). Isopach lines after Lucius (1948), Bintz & Muller (1965), information from drilling (compare Bintz & Muller, 1965), and own investigations (in the region Luxemburg - Mersch, around Echternach and in the german part of the outcrop zone). Age of the top of the formation after Muller (1980). Outcrop of the formation after Carte géologique de Luxembourg, tectonic information after Lucius (1948), Mertens (1982), Spies (1982).

3.- EXTERNAL CONTROL ON THE SEDIMENTATION

Sand wave evolution, bipolar current directions and systematic change of flow velocities indicate a tidal control on the sedimentation. The high flow velocities calculated in tidal channels and above shoals, as well as sand wave heights, can only be interpreted with the assumption of a d esotidal regime. Flow directions of the tides which are not directly opposite to each other (fig. 5) fit the paleogeographic situation (fig. 1). The SW-NE directed gulf of Luxemburg led to flow separation of the W - E running tidal wave causing flood directions to the NE and ebb directions to the south. The influence of the paleogeographical situation of the gulf of Luxemburg can also be made clear by comparison of the Luxemburg Sandstone Formation with the Minette Ironformation of Toarcian age. The Minette Ironformation originated in a similar paleogeographical situation in a meso- to macrotidal regime with similar flow patterns of ebb and flood currents (Teyssen, in prep.). It can therefrom be concluded that the Paris Basin in Lower and Middle Jurassic time has been a fully developed, tidal induced open sea basin with larger connections to both the Tethys and the northern ocean (compare also Ziegler, 1982).

An additional tectonic control on the deposition is obvious. Fig. 5 shows a zone of maximal thickness of the Luxemburg Sandstone Formation which directly coincides with the syncline of Weilerbach, one of the major tectonic elements of the mesozoic part of Luxemburg (Lucius, 1948). Synsedimentary activity of the structure can already be observed in the Rhaetian sedimentary record (Laugier, 1961 ; Mertens, 1982 . Spies, 1982). The thickness distribution of the Luxemburg Sandstone Formation reflects the structural situation of southern Luxemburg. This holds as well for the zones of greater thickness south of Mersch and around Differdange. These conclusions fit also the observations of the Minette Ironstones which were deposited in a basin around Differdange.

4.- DEPOSITIONAL HISTORY

Sands and conglomerates accumulated as a fully marine deltaic sand body within the Liassic gulf of Luxemburg. Deposition took place during progradation of the delta to the SW. The biostratigraphical age of the preserved top of the formation after Muller (1980) (fig. 5) is in accordance with the progradation of the delta. The delta generally migrated from the East to the West, but sediment transport to the east occured at times when the axis of the delta had already moved far to the west. Several discrete coarsening upward cycles can be identified, but the number of cycles differs from place to place within the studied region. The cycles differ from one to the next with respect to the material. In the area south of Mersch three cycles have been distinguished by comparing the feldspar content as a function of its grain size (Spies, 1982). Sediments with distributions of feldspar grain size with larger medians contain also larger amounts of garnet. The three cycles are separated by conglomerates. Schreck (1976) explained the Luxemburg Sandstone as a polycyclic succession. The outcrop zone of the formation contains only sediments of the distal part of the delta (deltafront) because of subsequent erosion. An existence of strand sediments as affirmed by Muller & Raschke (1971) and Berners (1981) does not seem to be probable. The facies suggests subtidal environments throughout the whole outcrop zone.

The terrigenous material of the Luxemburg Sandstone Formation was derived through the Eifel depression zone. The maturity of the sediments of the formation indicates a second cycle origin. Part of the material may be reworked from Rhaetian sediments, but that cannot account for more than 5 °/o because of mass balance (Schreck, 1976). Most of the material must be derived from the reworked Buntsandstein cover of the Eifel and the eastern Netherlands. Buntsandstein covered the whole Eifel depression zone as can be concluded from sedimentological investigations of the erosive rests of the Buntsandstein (Wurster, 1964). The southeastern part of the Netherlands must also have been eroded before the Upper Triassic, as Wolburg (1969, fig. 25) has shown that Rhaetian directly overlies Buntsandstein in that region. Triassic material from eastern Holland may have been transported by successive deposition and reworking southwards into the gulf of Luxemburg.

ACKNOWLEDGEMENTS

The authors thank J. Bintz and the geological survey of Luxemburg for good cooperation and financial support to the field work. Part of this study originate in two masters thesis, GM and EDS acknowledge A. Siehl, Bonn, for supervising their thesis. TT thanks M. Visser, Utrecht, and P. Homewood, Fribourg, for introduction to and discussion on tidal sand wave deposits. A. Siehl and P. Homewood kindly read and improved and early draft of the manuscript.

BIBLIOGRAPHY

ALLEN, J.R.L., 1980. Sand waves : a model of origin and internal structure. Sedim. Geol., 26 : 281-328.

ANDRZEJEWSKI, A., 1981. Geologische Geländeaufnahme zwischen Rollingen und Nommern östlich der Alzette (Luxemburg), granulometrische Untersuchung der Geröllhorizonte im Luxemburger Sandstein (Lias). Unpublished masters thesis, Bonn university, 125 p.

ANTUN, P., 1953. Les associations des minéraux denses du Mésozoique luxembourgeois. Ann. Soc. géol. Belg., 76 : 249-271.

BERNERS, H.P., 1981. Faziesuntersuchungen im Luxemburger Sandstein Westluxemburgs. Unpublished masters thesis, Aachen university, 154 p.

BINTZ, J., GUERLIN-FRANIATTE, S., MOUTERDE, R. & MULLER, A., 1970. Résultats des recherches géologiques faites sur la tranchée du S.E.B.E.S. : Trocon Eschdorf - Nospelt, Nospelt - Rébierg, Nospelt - Bridel. Publ. Serv. Géol. Luxem., 20 : 1-83.

BINTZ, J. & MULLER, A., 1965. Sur la représentation du "Grès de Luxembourg" sur la nouvelle carte géologique générale du Grand-Duché. Archs. Inst. gr.-duc. Luxem., Sect. Sci. natur. phys. et math., 31 : 241-258.

BOERSMA, J.R., 1969. Internal structures of some tidal megaripples on a shoal in the Westerschelde estuary, the Netherlands. Geologie en Mijnbouw, 48 : 409-414.

DEBRAND-PASSARD, S., 1980. Synthèse géologique du Bassin de Paris, Volumen II, Atlas. BRGM, Memoire n° 102.

HELLER, P.L., KOMAR, P.D. & PEVEAR, D.R., 1980. Transport processes in ooid genesis. J. Sedim. Petr., 50 : 943-952.

HEILMANN, H., 1979. Geologische Untersuchungen im Gebiet Buschdorf -Reckange (Luxemburg). Unpublished masters thesis, Bonn university, 102 p.

HOMEWOOD, P. & ALLEN, P., 1981. Wave- , Tide- , and Current- controlled sandbodies of Miocene Molasse, Western Switzerland. Am. Ass. Petr. Geol. Bull., 65 : 2534-2545.

LAUGIER, R., 1961. Observations sur le contact du Rhétien et du Keuper dans le quart nord-est du Bassin de Paris. Colloque sur le Lias français. Mém. Bur. Rech. Géol. Min., 4 : 605-616.

LUCIUS, M., 1948. Das Gutland. Publ. Serv. Geol. Luxem., 5 : 1-405.

MERTENS, G., 1982. Geologische Untersuchungen im Gebiet Schönfels - Lorentzweiler (Luxemburg). Unpublished masters thesis, Bonn university, 187 p.

MOWBRAY, T. de & VISSER, M.J., 1982. Subordinate current reactivation and the recognition of tidal deposits. IAS 3rd. Eur. Mtg. Copenhagen, Abstr., : 52-54.

MULLER, A., 1980. Luxembourg. *In :* Geologie des pays européens : France, Belgique, Luxembourg. Congrès Géologique International, Paris.

MULLER, A., PREUGSCHAT, F. & SCHRECK, H., 1976. Tektonische Richtungen und Faziesverteilungen im Mesozoikum von Luxemburg - Lothringen. Jber. Mitt. oberrhein. geol. Ver., N.F., 58 : 153-181.

MULLER, A. & RASCHKE, P., 1971. Der Luxemburger Sandstein im Gebiet Syren, Munsbach, Sandweiler, Itzig, Hassel (Luxemburg). Publ. Serv. Geol. Luxem., 4 : 1-28.

SCHRECK, H., 1976. Ein Schüttungsmodell des Luxemburger Sandstein in der Mulde von Weilerbach (Luxemburg). Unpublished Ph. D. thesis, Aachen university, 168 p.

SOUTHARD, J.B., 1971. Representation of bed configurations in depth-velocity-size diagrams. J. Sedim. Petr., 41 : 903-915.

SPIES, E.-D., 1982. Geologische Untersuchungen im Raume Mersch - Lintgen (Luxemburg). Unpublished masters thesis, Bonn university, 177 p.

TEYSSEN, T., 1983. Physical model and FORTRAN IV program to estimate paleotidal flow velocities from features of sand waves. Computers & Geosciences (in press).

VISSER, M.J., 1980. Neap-spring cycles reflected in Holocene subtidal large-scale bedform deposits : a preliminary note. Geology, 8 : 543-546.

VISSER, M.J. & DE BOER, P.L., 1982. The effect of the diurnal inequality on tidal sediments : a tool in the recognition of tidal influences. IAS 3rd. Eur. Mtg. Copenhagen, Abstr.,: 88-90.

WOLBURG, J., 1969. Die epirogenetischen Phasen der Muschelkalk und Keuper-Entwicklung Nordwest-Deutschlands, mit einem Rückblick auf den Buntsandstein. Geotekt. Forsch., 32 : 1-65.

WURSTER, P., 1964. Geologie des Schilfsandsteins. Mitt. geol. Staatsinst. Hamburg, 33 : 1-140.

ZIEGLER, P.A., 1982. Geological Atlas of Western and Central Europe. Elsevier, Amsterdam.