Results of Recent Terrace Research in the Middle Rhine Valley

A lot of questions concerning the sequence of terraces in the Middle Rhine Valley as well as their genetic dependence on geological, geomorphological and climatic processes remain insufficiently answered. So far, three issues in particular have required further examination: -The phenomenon of the horizontal consistency ("Horizontalkonstanz") of the main terraces cannot be explained coherently. -Studies from adjoining valleys of the Nahe and Lahn rivers, have identified larger numbers of terraces within the upper terrace group (ANDRES & SEWERING 1983; GÖRG 1984; SEWERING 1993). -Unsolved problems concerning the positions and ages of the older (äHT) and younger (jHT) main terraces. Given these problems, we started re-mapping the terraces of the Upper Middle Rhine Valley by conducting numerous borehole drillings. Our results, which we combined with the findings presented in previous studies, demonstrate the existence of a total of 28 alluvial sediment bodies in the valleys of the rivers Nahe and Rhine between Bad Kreuznach, Bingen and Boppard (GÖRG 1984; PREUSS 1983; ANDRES & PREUSS 1983; PREUSS, BURGER & SIEGLER 2015). For the Lower Middle Rhine Valley we mainly used the publications of BIBUS (1980), HOSELMANN (1994) AND BOENIGK & HOSELMANN (2003). For the Moselle and Lahn CORDIER et al. (2006, 2014) and SEWERING (1993) provided helpful insights. Further information was obtained from FUCHS et al. (1983), BIBUS & SEMMEL (1977)AND SEMMEL (2009).

.The Downstream Correlation Diagram (DCD) of river terraces in the Lower Nahe and Upper Middle Rhine Valley (see Fig. 1) contains 28 alluvial sediment bodies. They were identified at key locations with more than 720 borehole drillings, many of them in clusters, which in most cases reached the rockbed of the river terraces. The field work was based on contour level maps derived from a LIDAR terrain model. The older studies at the Nahe (GÖRG 1984) and in Rhine Hesse (PREUSS 1983) was based on the German Basic Map, scale 1:5.000 ("Deutsche Grundkarte 1:5.000"). Our findings show that the upper group of terraces consist of at least 17 distinguishable terrace levels, which correspond to the sequences of the Nahe and Lahn valleys (GÖRG 1984, SEWERING 1993). Taking the results of GÖRG (1984) into account, further 11 levels can be identified below the jHT in the Lower Nahe Valley. In Fig. 1 the gradient of the Palaeo-Rhine (see the triangles between 240-270 m a.s.l.) is inversely inclined to the river´s current flow of direction - namely to the south, river terraces between 200 m a.s.l. and 170 m a.s.l. are arranged more or less horizontally and river terraces below 140 m a.s.l. have a normal gradient to the north. This diagram shows that the hypothesis of a missing gradient is obsolete, but at the same time the longitudinal gradients are obviously affected by tectonic processes (see green line in Fig. 1).

Using the idea of VAN DEN BERG (1996), a collected sequence of Nahe and Rhine terraces was arranged, using their discernible trends (see Fig.2). The elevations of the terrace bases from this collected sequence were matched to the cold periods of the thermal interpretation of the results of pollen analysis in the Netherlands (ZAGWIJN 1985, 1998), which in turn were correlated to the diagram of the Marine Isotope Stages (COHEN & GIBBARD 2011). Using this approach, we obtained a correlation with climatic events of the last 2.7 million years, the standard NW-European Stages and an approximate age for the river terraces.

In the third diagram the collected chronosequence of Nahe an Rhine was compared with the chronosequence of the Maas (see Fig. 3). Two linear trends are visible in the diagram, one between 0.7 Ma and 2.7 Ma, the other between 0.14 Ma and 0.5 Ma. The gradients of the linear equations are 52.37 m/Ma for the older and 66.13 m/Ma for the younger period. These values are fluvial incision rates, but they can be interpreted as tectonic uplift rates as well. The difference of 14 m/Ma is interpreted as a subsidence rate of the collected chronosequence. Of further interest is the period between 1.04 Ma and 0.51 Ma, which marks an excessively changing environment, visible in the climatic records of the Marine Isotope Stages (MIS) and in the incision rates.

An explanation model for the changes in slope of the longitudinal gradients of the terraces of the upper terrace group could be derived by considering the direction and the amount of recent crustal movements in this area, which have been measured by MÄLZER et al. (1983) with the help of precision levellings (see Fig. 4). Uplift processes can be observed north of the mouth of the Lahn, and subsidence processes southeast of it. The course of the River Rhine is thus located in a zone of crust which is inclining contrary to the gradient of flow. From there the wider research area is uplifted and partly lowered, depending on geotectonic processes of the Upper Rhine Rift Valley in the south. To localize the tectonic processes, the crust-mantle boundary and epicenters were integrated (FRANKE et al. 1990; USSGS 2002; LEYDECKER 2005).

The tectonic setting can be visualized with a geomorphological map of river incisions (see Fig 5). In it we see the consequences of the collision of Africa and Europe, the uplift of the Alps, the creation of the uplifted uplands to their north and the Rhine Graben. The river incision is the calculated difference between the base of the relief, i.e. the tangential plain to the thalweg of the valleys, and the SRTM-topography. The valleys in some uplifted areas are deep (> 100 m, red), in the uplands the incision of the rivers is mainly 75-50 meters (dark green). The crust-mantle boundary localized the tectonic processes.

A simple model could be calculated and designed with data from the collected chronosequence of Nahe and Rhine terraces, especially with the calculated subsidence rate of 14 m/Ma (see Fig. 6). With it the terraces could be virtually uplifted again. The base of the tRh 1. is actually at 274 m a.s.l. and has been lowered by 37 m within 2.71 Ma. Therefore the thalweg back then was positioned at 311 m a.s.l. Finally, the actual height of the rockbeds of the terraces of the collected sequence were connected to the heights of the mouth of the Lahn with red lines. The graphical result is more or less the same picture as in the DCD (Fig. 1.). The missing gradient of some river terraces is therefore the product of the subsidence of the Upper Middle Rhine Valley.

The terrace model was evaluated with two datasets from the Lower Middle Rhine Valley (BIBUS 1980, HOSELMANN 1994) (see Fig.7). We could observe that the test data fits quite well into the framework of the model. Therefore we think that the ages of the terraces, based on their correlation with the data of ZAGWIJN (1985, 1998) and COHEN & GIBBARD (2011) are quite good and representative.

Source: PREUSS, J., BURGER, D. & SIEGLER, F.: Neue Ergebnisse zur Gliederung und zum Längsgefälle der Talbodenniveaus im Mittelrheintal und an der Unteren Nahe: Revision der Hypothese der Niveaukonstanz, Berücksichtigung des Modells der aktuellen Höhenänderungen, Korrelation der Terrassensequenz mit den Marinen Isotopen Stadien und den Terrassen der Maas. Mainzer naturwissenschaftliches Archiv, Band 52, S. 5-75, 19 Abb., 8 Tab., Mainz, 2015.

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