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Paradoxes in the development of gullies

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Abstract: Gullies in the temperate zone are the products of linear erosion, piping and mass movements active mostly during heavy rains. On dominant role of one of those three co-operating processes decide the parameters of rainfalls and permability of substratum. The diversity of gullying depends also on the inherited relief and stage of development of gully forms. In the cultivated areas the formation of gullies is initiated also by cart-roads.

Keywords: gully formation, linear erosion, piping, mass movements, rainfall intensity, permability of substratum

Introduction

After textbook definition the gully is an erosion form developed mainly on the slope or in the axis of valley floor. It is formed by linear erosion although other processes may take part in their formation. As erosion form it should have young features, but in reality is passing various stages of evolution. A diversity of physical parameters of substratum of inherited relief and especially of rainfall intensity and duration creates great differentiation among geomorphological phenomena, which we call together as "gullies".

Duration and intensity of rainfalls against permeability of substratum

Type of rainfall plays frequently a leading role in the distribution of runoff into overland flow, subsurface throughflow and ground flow (Słupik 1981, Starkel 2006, 2011). During high intensity downpours (1–4 mm min^{-1}) the dominant overland flow creates on slopes without dense vegetation cover the rills, which gradually may be transformed into erosion gullies. Continuous rains of lower intensities facilitate deeper infiltration and either initiate the formation of subsurface channels (by piping) or the saturation of soil is leading to earthflows. The most effective are the events with downpours super-imposed over continuous rains. The longer duration of rain, frequently in the form of clusters strengthens the growing of new gully.

The structure of runoff is parallely controlled by physical parameters and permeability of substratum (Starkel 2011). On the sandy soils rain infiltrates deeper and only during very high intensity rain, the gullying may follow. Subsurface flow is leading to transformation of tunnels into blind valleys and finally to normal gullies. On steeper slopes the saturated ground could reach even a stage of liquefaction and the formation of new gully is initiated by shallow earthflows.

On the contrary the less permeable soil support an overland flow with formation of rills and in the floors of tributary valleys the deluvial and proluvial deposits are incised by new generation of gullies.

Therefore studying the gully development we take into consideration both factors controlling water circulation: parameters of rainfalls (or melting water) and substratum which jointly decide on type and rate of gully formation.

Role of inherited landscape

The relief and overlying covers inherited from previous epochs may also influence on the areal pattern of gully formation. The periglacial covers and forms in the uplands and basins of Central Europe deliver many examples on the impact of inherited relief pattern on the diversity of gullies and their mo-

saic distribution. In this region prevail three types of relations (Starkel 2005).

The first one is characterized by structure controlled ridges rising above flat feet covered by several meters of colluvial or deluvial deposits. Water flowing downslope infiltrate in these sediments and shallow gullies may initiate from the upper part as blind valleys or on the contrary new gullies develop from the bottom by the dissection of erosion scarps. In the Flysch Carpathians in wide headwater niches filled by older colluvia follows the rejuvenation of V-shape valleys by retreating erosion supported by piping.

The second way of evolution is connected with dissection of older form buried by thick loess or other periglacial covers and dismembering of erosion scarps by subsurface drainage system mainly through piping or variety of mass movements. This type is common over extensive loess plateaus.

The third type is characteristic for thinner loess blanket overlying resistant bedrock (limestone, chert etc.). In such cases the deepening of gully is blocked and cutting of V-shaped gully in the rock can continue depending on stream power.

Coexistence of various forming processes

In the development of gully participate linear erosion (surficial), piping and earthflows. Each of these processes could be the main creator of gully in its initial phase (Fig. 1). But also in later stages of gully evolution different processes cooperate and even may play a leading role (Starkel 1959, Starkel & Basu 2000). Therefore we should be very carefull in reconstruction of processes forming particular gully only on the base of actual survey. In large gully system we observe that in the whole network exist various generations, which vary, from initial forms to mature and senile. Usually the leading vertical component of linear erosion supported by piping in younger stages is later being replaced by widening of gully through slope retreat by various types of mass movements. In the senile stage the intensity of all processes is reduced (depending also on the character of vegetation cover) and in the valley floors the aggradation is continuing (Fig. 1). After heavy rains the gully may be rejuvenated by the dissection of deluvial-colluvial deposits.

More distinct differentiation of processes exists in the longitudinal profile of developing gully, the separate sectors of which are in various stage of evolution. It is the effect of gully growth which is usually proceeding upslope. Frequently the proluvial fan fills the lower sector, when the uppermost one is in the initial stage with collapsing subsurface tunnel. In longer gully system we can observe even two-story or three-story system of alternating erosion and depositional sectors.

Gullies and human activity

In the present development of gullies the impact of various human activities must be taken into consideration, both in the creation of new form as in their accelerated maturization. In the cultivated areas many cart-roads have been gradually incised up to several meters and after heavy downpours may be transformed into a narrow gully and abandoned.

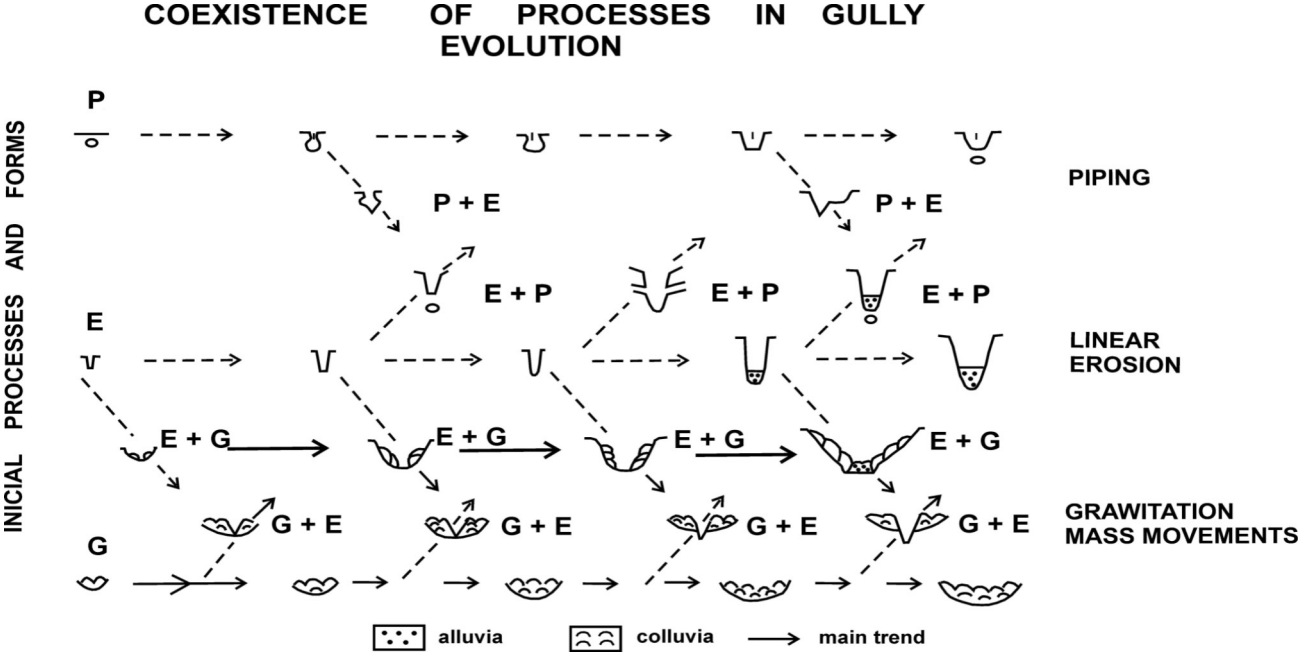

Fig. 1. Coexistence of three leading processes: linear erosion, piping and mass movements in evolution of gullies

Primary origin is indicated only by the pattern of such gullies, which are corresponding with field-road system.

After taking under cultivation the mature gully slopes are gradually more gentle. Farmers may level every new deeper rills or piping holes in the floor formed after heavy rains.

Final remarks

Gullies are characteristic feature of degradation and dismembering of slopes, especially in areas without dense vegetation cover. These are the products mostly of heavy rains, during which processes of linear erosion, piping and mass movements are active. In various stages of evolution the role of particular processes is changing (Fig. 1).

Gullies in the present-day temperate zone are characteristic for post-periglacial relief, covered mainly by thick mantle of finegrained sediments in which after melting of permafrost water may infiltrate in the ground and runoff is concentrated in surficial and subsurface channels. This linear process may be also sponsored by human activities.

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