Delta morphology on Mars

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Research group
River and delta morphodynamics

Aim

- Delta deposits have been identified on Mars
- Mars could either have had a sustained warm and wet climate or a cold and dry climate with episodic flood bursts
- We want to know how long it took to form the deltaic deposits on Mars

Background

- At least four different types of delta deposits on Mars; formative conditions (such as water discharge, sediment type, duration of formation) unknown (see Fig. 1)
- These four types can be grouped into two main classes of deltas:
    - Formed under rising water level or formed under steady/falling water level
- These two main classes of deltas have been formed in the laboratory under known conditions (see Fig. 2)
- In profile, these two classes are very different:
    - Retrograding (back-stepping) or prograding (Gilbert-type)
- We have used a model developed by Kleinhans et al. (2009) that calculates the growth of a deltaic sedimentary body into a basin with rising water level (see Fig. 3)

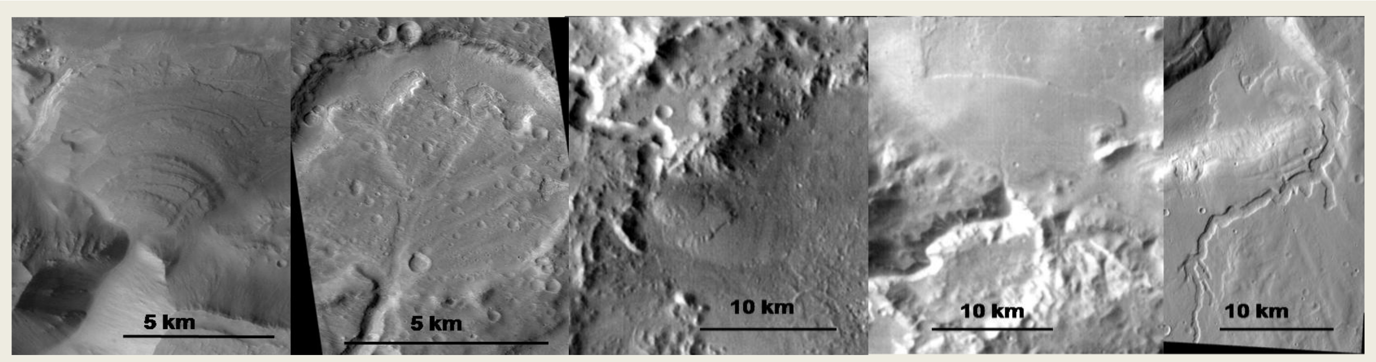

Fig. 1: Different types of deltas on Mars.

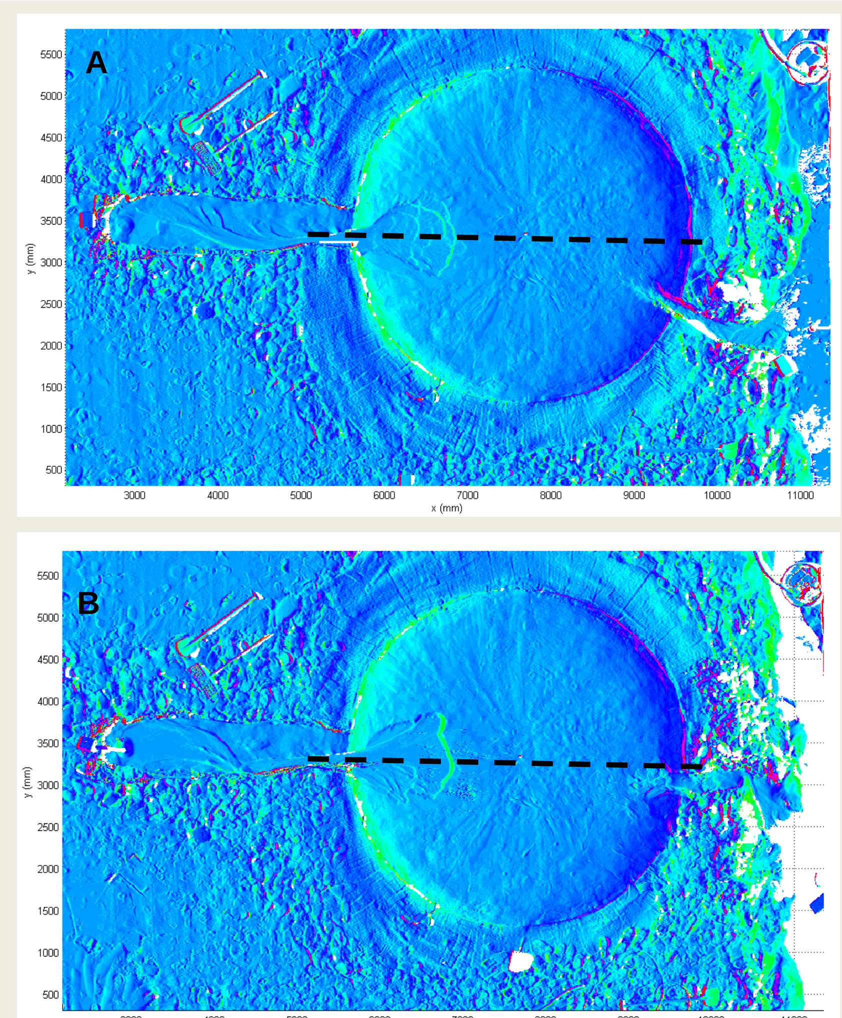

Fig. 2: Shaded DEMs of retrograding (A) and prograding (B) deltas formed within impact crater lakes in the laboratory. The black lines are the locations of the profiles shown in Fig. 6.

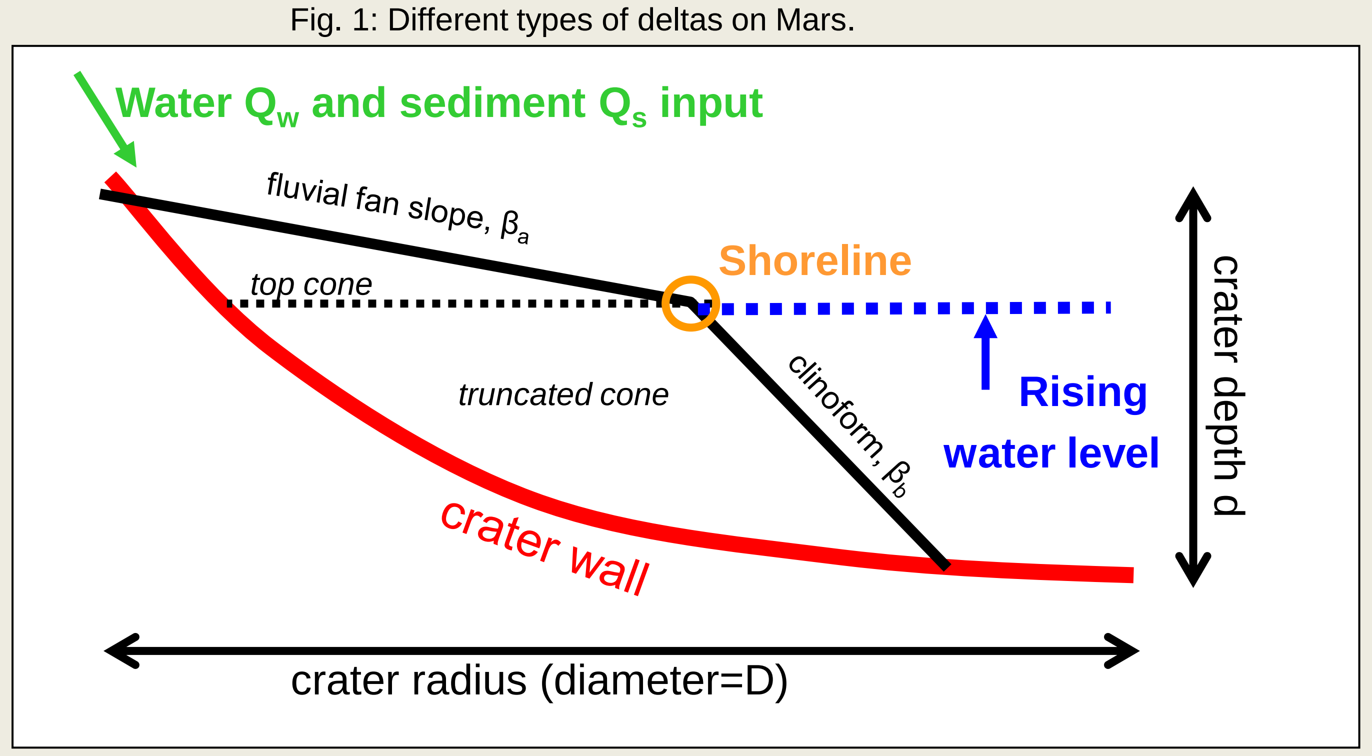

Fig. 3: Schematic drawing of the numerical model used to predict delta morphology.

Methods

- Model calculates the development of the subacqueous truncated cone (with angle of repose (see de Vet et al. 2010 - this conference; abstract #P53Q-1510) and subaerial top cone
- We run the model for different laboratory scenarios, all filled only approximately 85%:
    - A small crater vs a big crater (2m vs 4m diameter – no vertical exaggeration in the big crater)
    - Low vs high discharge (0.07 m/s vs 0.35 m/s)
- We show the good correlation between the profiles of Martian deltas from topographic data and those obtained from running the model for different scenarios on Mars
- We compare the profiles of our laboratory deltas with those generated by the model in order to say something about the processes that are involved in the construction of a deltaic deposit
- Sediment transport rates are predicted by Parker's formula or calculated directly from the lab delta volumes

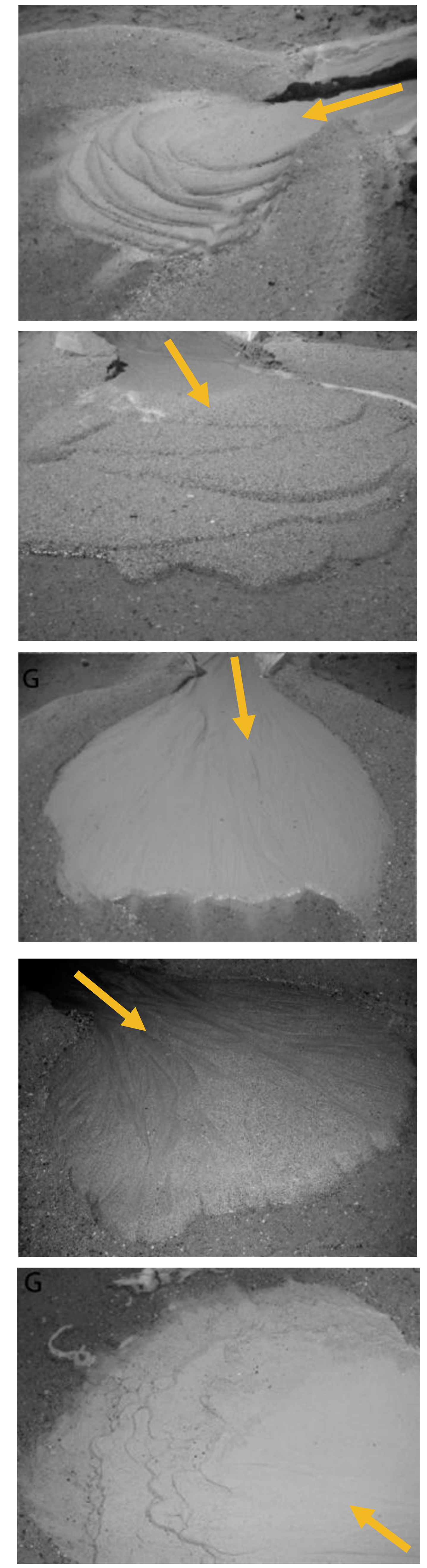

Fig. 4: Photographs of laboratory examples of retrograding and prograding deltas within crater lakes. Arrows indicate stream-flow. Note the different morphologies resulting from different discharges, different sediment types, and water level positions (rising/falling).

Results

From the model, we see that:
- The small crater (2x vertical exaggeration) did not fill much quicker relative to the big crater
- High discharges (high water:sediment ratios) are responsible for smaller deposits within the crater

Comparing the model with the lab results, we see that:
- Sediment pulsing (variation in sediment availability for example due to upstream bank collapse) has a significant effect on the morphology and is the main factor responsible for the step-like profile(see Fig. 5)
- Sediment transport is much higher during the initial phases of fan development (probably due to high sediment availability in the unconsolidated crater rim), and then much less during the rest of the development (see Fig. 5) – hence we see a distinct *change from dense flow to dilute flow* during the formation of the deposit.

Comparing the model to Mars, we see that:
- The average gradient is comparable and the simple model is successful (see Fig. 6)

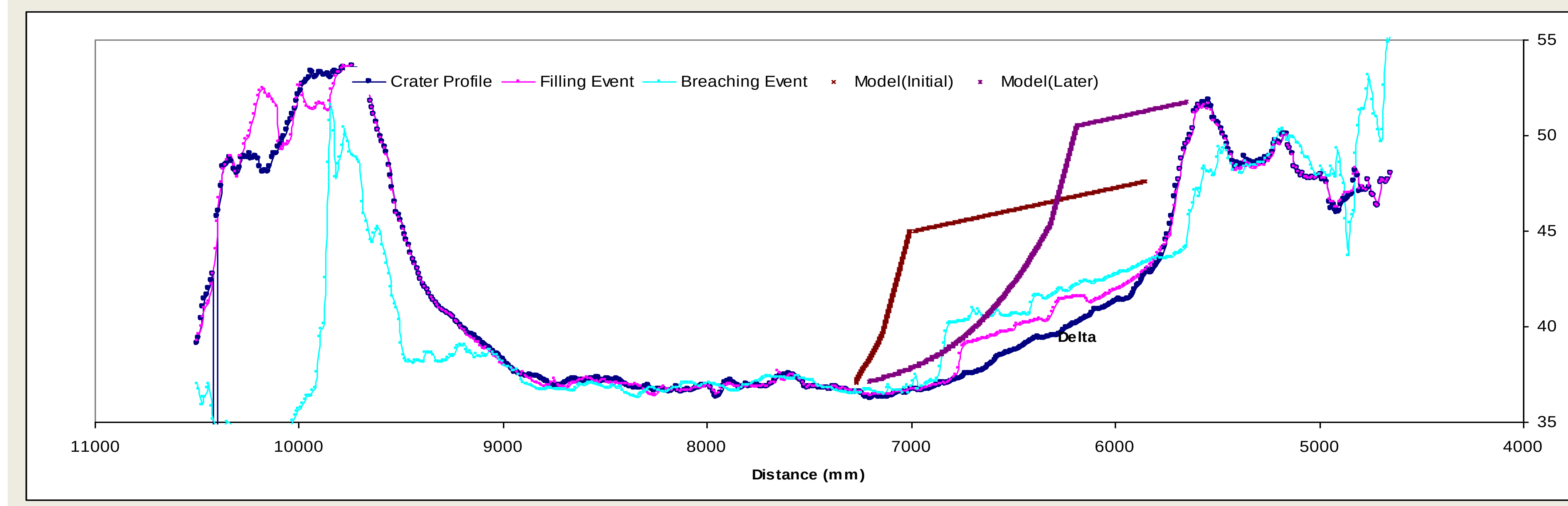

Fig. 5: Longitudinal profile for high discharge lab scenario for the large (4m) crater, both filling and breaching events (only the filling event is modelled). Two models are shown: a highly concentrated flow for the initial development, and a more dilute flow for the rest of the time. Flow is from left to right.

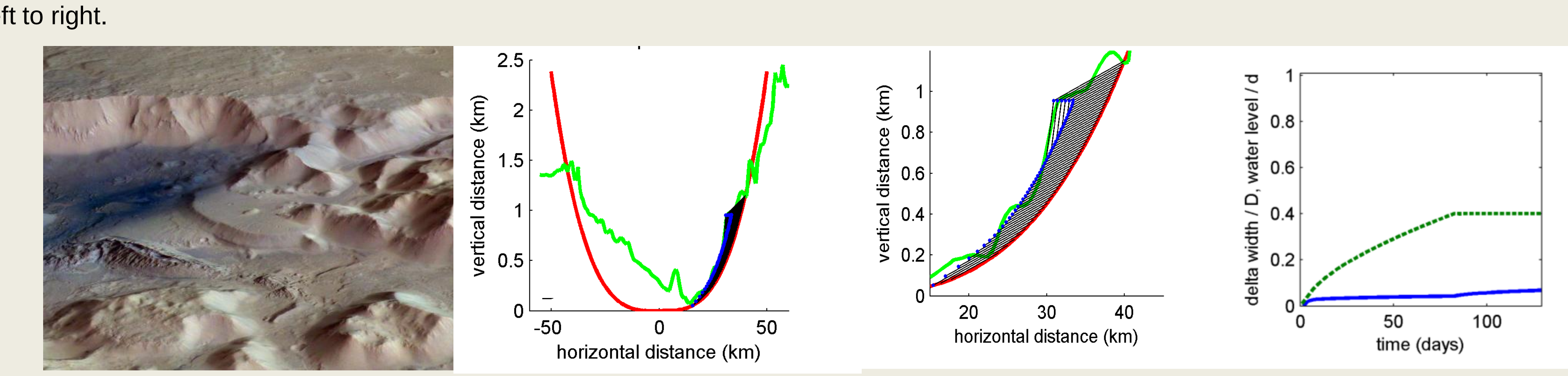

Fig. 6: Model profile compared to a real Martian delta profile (Nepenthes). Green line is the HRSC topography.

Conclusions

- Two different types of deltas in the laboratory – retrograding and prograding – based only on the effect of the rising or falling water level
- Our numerical model only predicts the morphological evolution of a delta in a basin filling with water, assuming constant inflow of water and sediment.
- Pulsing in sediment transport, as observed in experiments, causes steps in the fans on Mars and in the lab
- Experiments show steep profiles in the rising stage because debris flows occur initially due to the unconsolidated sediment in the rim. A fast decline in transport rate causes more rapid drowning than the model predicts
- We deduce that deltas on Mars can have formed in one short event, and their various shapes are explained by different stages in evolution from filling to overflowing basins.