LACUSTRINE DELTAS IN MARTIAN IMPACT CRATERS: MORPHOLOGIES, TYPES, AND SIGNIFICANCE. Nathalie A. Cabrol and Edmond A. Grin. NASA Ames Research Center/SETI Institute, Space Science Division, MS245-3, MoffettField, CA, 94035-1000. Email:ncabrol@mail.arc.nasa.

1. Introduction

Deltas are being intensively studied on Earth in the context of oil investigation, and therefore deltaic facies models have become relatively well-established (Broussard 1975, Coleman and Prior, 1082, Miall 1984, Elliott 1986, Whateley and Pickering 1989, Collela and Prior 1990). They are defined as discrete shoreline protuberance formed where rivers enter oceans, semi-enclosed areas, lakes or lagoons and supply sediment more rapidly than it can be redistributed by basinal processes (Elliott 1986). They are classified into majors groups with often many transitional forms: river-dominated, wave dominated, and tide-dominated, with distinctive associated morphologies.

In previous works on martian deltas, De Hon (1992) and De Hon and Pani (1992) used these morphological indicators to search for traces of wave action from a large body of water that would have been located in the Northern Plains of Mars, but they could not demonstrate their presence. As De Hon suggested (1992), the estuarine deltaic constructs could have been possibly eroded away with time, and/or, buried by later fluvial activity, when the ocean was not anymore there.

2. Deltaic Structures in Impact Crater Lakes

In the case of the present study, we are confronted to river-dominated deltas observed in ancient martian impact crater lakes (Cabrol and Grin 1999, Cabrol and Grin 2000 submitted). The potential variables in these environments are: (1) the crater basin-type, that can be closed, open, or a lake-chain, as defined by Cabrol and Grin (1999). The type influences, for instance, the velocity of the flow, the rate of erosion and sedimentation, and the rate of evaporation, (2) the regularity of water activity (volume and occurrence), (3) possibly the global climate changes through time, the regional and/or local climate influence, and possibly a latitudinal factor for deltas that were formed during the same geological periods, (4) the magnitude of local/regional erosion in the geological period that followed the last lacustrine event. Considering this particular variable, we will assume it as negligible in our study, since the impact crater lakes surveyed were the ones that were obviously not destroyed by geological processes of great magnitude. Finally, river-dominated delta evolution and morphologies also depends upon the relative density of water. If the channel water is more dense that the lake water, the sediment load will be coarse-grained. Small, steeply deeping elongated deltas will tend to form with fine-grained material deposited further away as density overflow (Bhattacharya, and Walker 1992). Also defined as inertia-dominated (Bates 1953), these deltas are often observed in alpine and periglacial environments. When both channel and lake water densities are equivalent, they tend to more easily mixed. In shallow water, this will result in the formation of the so-called Gilbert deltas (Gilbert 1885), generated by friction at the bed level, rapid deceleration of the flow and development of middle ground-bars that cause distributaries to bifurcate. Recently, Ori and Baliva (1998), and Ori and Marinangeli (1999) suggested that Gilbert deltas are observed on Mars. These deltas are characterized by steep foresets, less steep topsets and bottom sets. Finally, if the channel water density is less than the lake density, the sediment-load is transported further away. Because of the tendency of these sediments to be carried as a buoyant plume, the resulting deltas are also called buoyancy-dominated mouth bars (Harris 1989, Pulham 1989, Martinsen 1990).

3. Morphologies and Types

We discuss the most representative lacustrine delta morphologies that we observed in impact crater lakes (Cabrol and Grin 1999, 2000-submitted-). Among all crater lakes, many had deltas partially destroyed by erosion or subsequent impact cratering. We found 36 of them that could be used to establish a typology for the martian crater lakes The three main-type we observed are:

- fan-like delta,
- elongated delta, and
- lobate delta, as well as transitional forms for each of these three types. As demonstrated by terrestrial examples, the morphology of the deltas is a good indicator of the grain-size composition in the deltaic structure, and of the characteristics of the water in the inflowing channel and basin. The volume of sediment and water necessary to transport and deposit the sediment, and to construct these structures in discussed in Grin (2000, this LPSC Conference).

Therefore, even if we cannot currently access directly the information about grain-size and flow characteristics, the delta morphologies might help unravel key-components of martian fluvio-lacustrine dynamics in impact crater lakes.

4. Deltaic Dynamics and Significance

The morphology of deltas (Figure 1.) reveals how water and sediment from the rivers meet and mix in the lacustrine environment. Two main situations are envisioned: (a) one is the buoyancy-driven flow resulting from water density differences related to water salinity and/or temperature differences, and (b) the other one is the inertia-driven flow into lake or sea, also called jet (Write and Coleman 1973, Galloway 1975, Wright 1977, Bowman and Iverson 1978, Allen 1985, Allen 1997).

The dynamics of the outflowing water and sediment load is controlled by a number of factors that include the characteristics of the water, the bathymetry and energy of the receiving basin (Allen, 1997). This dynamics may vary also for the same river along the year. When the river enters a basin water of almost equal density, the mixing and deposition of the sediment load is rapid and forms the so-called Gilbert-type deltas. Potential examples of such deltas are Ma'adim Vallis delta in Gusev crater, the delta formed by the derivation of part of the Ares Vallis flow in the Aram Chaos basin, as well as deltas presented by Ori and Baliva (1998) and Ori and Marinangeli (1999).

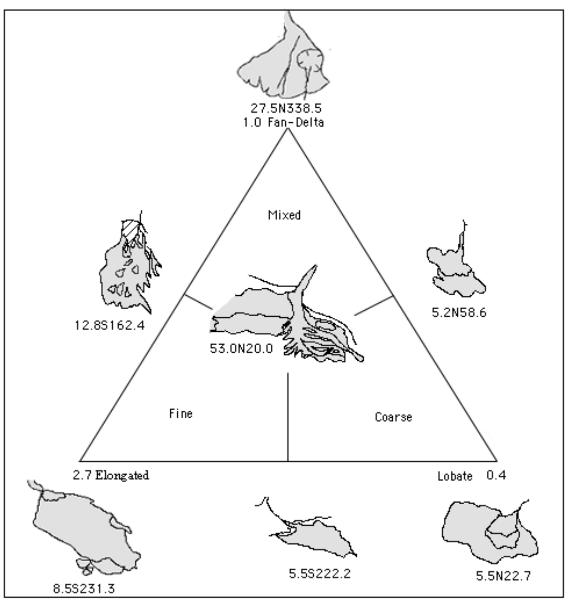

Figure 1. Typology of Martian Deltas in Impact Crater Lakes and Plausible Sediment Grain-Size Interpretation. (Numbers correspond to the crater lakes coordinates). These examples are extracted from the global survey of Martian Impact Crater Lakes (*after Cabrol and Grin,1999. Icarus 142, and Cabrol and Grin, 2000. Icarus, submitted* -)

The size and shape of a delta is determined by the subdelta bathymetry, which is function of the configuration of the crater bottom over which the delta progrades and the influx rate and the texture of the fluvial sediment. The density contrast between the tributary and the standing body of water determines how the stream deposits its load. When the stream emerges from the channel with a sufficient inertia momentum, which depends on the velocity that can maintain this momentum at some distance of the channel's mouth, the flux forms a flat plume. The deceleration of the flow gradually drops sediments. Coarse sediments are deposited near the mouth, and fines are carried well over the delta slopes. This process forms an elongated structure in the axis of the channel. Much of the fine-suspended load is deposited on the lateral margins of the flat plume, where the momentum is lower and forms a fan-shaped or lobate margin configuration. The marginal deposits are finer-grained and better sorted than the deposits in the axis of the channel. They grade downward into prodelta muds and are transported along shore during the formation of the delta, The rise of the water level in the ponding basin generates the formation of a coarse-grained steep delta front. The lowering of the water level causes the dissection of the delta by channels. The stratigraphic sequences are the most climatically sensitive: fan-lobe deltas are indicative of arid period (and/or small amount of water); elongate delta plains indicate high-discharge periods; entrenchment and dissection indicate the resurgence of water influx; successive fan lobes are the results of cyclic discharges; channelized deltaic mesas are indicative of forced subglacial discharges under ice-covered lakes (Grin and Cabrol, 1997).

Our poster will present the hydrological, climatological, and potentially exobiological significance of the observed deltas in martian impact craters through time.

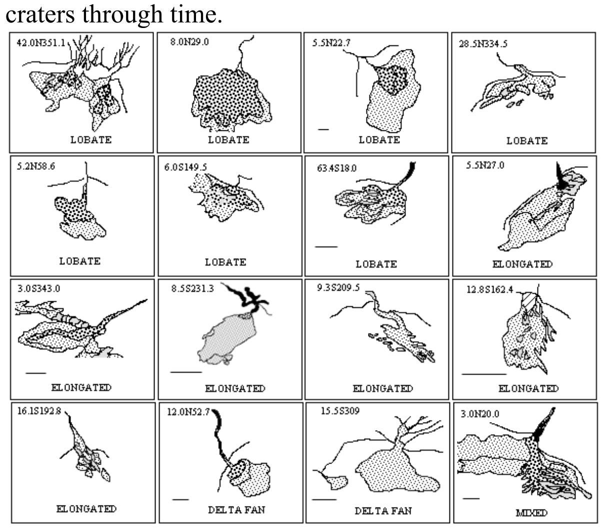

Figure 2. Some typical examples of deltas observed in martian impact crater lakes and corresponding classification. They are consistent with the elongate to lobate types observed in terrestrial river-dominated deltas. The delta-fan type represent only few examples. (*After Cabrol and Grin, 2000 Icarus, submitted*). The scale bar represents 5-km.