FRACTALITY OF VENUSIAN EJECTA OUTFLOWS; J. You, K. Kauhanen and J. Raitala; Department of Geosciences and Astronomy, University of Oulu, Oulu, Finland

Many terrestrial lava flows as well as outflows on other terrestrial planets have fractal properties [1, 2, 3, 4, 5] which may indicate something of the geological processes involved. 402 impact craters between 1.5 km to 280 km in diameter have unusual outflow features [6]. Fractal properties of outlines of crater ejecta blankets and ejecta flows on Venus were investigated for 18 Cytherean craters by analysing Richardson plots of crater ejecta blankets and ejecta flows. Fractal dimensions of Venusian crater outflow margins were calculated by the structured walk method where the apparent length of an outflow outline was measured by different rulers. This length increases as the ruler decreases since smaller rulers fit better to smaller-scale embayments and protrusions along the outline. Fractality can be found from the linear trend in the resulting R-plot. The distinction between fractal and nonfractal behaviour is, however, arbitrary and subjective. The fractal dimension of crater outflow margins which are nonlinear and have numerous embayments and protrusions should be from 1 to 2.

Crater outflows originate from inside or under the continuous ejecta blankets, continue downhill into the surrounding terrain and can be distinguished from the continuous or hummocky ejecta blanket by their length, brightness, nonradial distribution, complex morphology, and/or sinuous planform [7]. Usually they have flow-like or channel-like apperance which can not be explained by any ballistic process. These outflow features are very diverse in appearence and length. Close to the crater outflow may produce tributary channels and steamlined islands which disappear farther along the the outflow´s course [8]. Some are like erosional flow channels with clear margins or levees but most are like broad deposition fields without main structures apparent in radar imagery [7]. Large craters produced by relatively low-incidence-angle impacts may be more likely to produce flows than small craters produced by higher-angle impacts [9]. The abundance of craters with outflows changes with diameter as well as with the planform symmetry of the crater rim materials. Percentage of craters with outflows generally increases with crater diameter, possibly because amounts of impact melt and ballistic ejecta are larger in more energetic events. Oblique impacts remove efficiently impact melts from the craters resulting in a possibly positive relation between decreasing impact angle and increasing length and areal coverage of outflows [8].

The relation with the local topography varies and in some places outflows may also surmount structures of considerable height [8]. The identity of these fluids is not clear and their emplacement mechanisms are not understood. The role of the atmosphere on Venus in outflow emplacement may have been important. High surface temperature and atmospheric pressure on Venus result in large amount of impact melts. The amount of impact melt may be even 3 times that on the Moon for a given crater diameter [9]. The melt separation processes are also more efficent due to higher surface temperature and pressure and larger ejecta particle size. The crater outflows have had a high fluidity, possibly due to significant amounts of impact melts and hot gases. Part of the dense atmosphere may have been involved to form a hot turbidity flow [7]. The resulted low-viscous fluids have flown over long distances. There are outflows that appear to have been deposited before the crater rim while some other outflows postpone the crater rim material emplacement. Outflows deposits are generally rather thin and their flow directions are controled by local topography following to crater flanks and shallow valleys [8].

Fractal dimensions of these structures obtained by the structured walk method may help to identify and classify some of the impact-related processes. The R-plots can be divided into two parts: the first linear part at the beginning and the second linear part in the middle. Beside these main linear parts the common features of the plots may also include scattering in the middle of the second part, smooth scattering over the entire second part or a strong scattering in the end of the plot. Various parts of each individual R-plot display effects of fractal mathematics, characteristics of local geology or some impact-related processes. The first linear part and the main scattering at the end are influenced by the ruler which is close to the pixel size or approaches a considerable part of the measured outline length, respectively. The upper scale of

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the second part is related to the measured perimeter and there is a maximum ruler length beyond which the ruler will not fit the outline properly. Relation between this value and the perimeter is obvious and rulers exceeding ≈1/10 of the perimeter will not follow it very well. The second linear part of ejecta blankets reveals fractal properties, possibly related to impact-related ejecta and flow processes. Variations in this second part indicate differences in the crater formation and geology. The studied data allows only a few common features to be found and investigated further. The existence of two linear subparts in the second part may indicate a change in fractal properties due to processes active in different scales. The middle scattering indicates the size range of studied lobes and bays. The wider this scattering is the higher is the variation in this lobe size. A larger scattering amplitude indicates the existence a few longer ejecta lobes but may also reflect effects of a non-fractal process or several overlapping processes. A smooth scattering over the entire second part may be depend on vertical impact angles or low impact energies. Previous study of relation between the fractal dimension of the second part and the perimeter of the ejecta outline indicated a positive correlation [10]. Relation between the perimeter and the ratio of the square of the ejecta perimeter divided by the ejecta area had a similar trend as well as the relation between the fractal dimension of the second part compared to the square of the ejecta perimeter divided by the ejecta area.

The extended study of impact flows made by two independent measurements of fractal dimensions of the outflow outlines in different scales has provided quite precise information of their fractal dimension values. The outflows from craters with diameter above 50 km seem to fall into a'a type while outflows from craters with diameter below 50 km tend to be more pahoehoe-like. Although the fractal dimension of a same outflow measured from different image resolutions appears to have almost the same value, too large differences in resolutions may effect measurements of the fractal dimension due to some limitations in algorithm, routines in finding the outflow outline or the outline may be scale-dependent nature of outline.

The observed outflows are diverse in appearance and may represent more than one process and/or material. At least two emplacement processes are proposed for the outflows [7]. The first one includes modification of the continuous ejecta blanket after the ejecta emplacement. If deposition preceeded ejecta emplacement a flow stratigraphically underlies the ejecta blanket, possibly associated with early jet, vapour, magma and fluidization phase of the impact event. This material may have had some capacity to flow uphills for short distances.

The high variation in fractal dimensions for outflow outlines of small craters may be due to the fact that the topography and geology of their immediate local environment has relatively more effects than in the case of larger craters. Some impact-related outflow emplacement processes seem to operate on a certain self-similar scale range which can be observed as a linear trend in R-plots. These R-plots of crater outflow margins reflect some of the outflow properties. This method may help us to locate our research objectives and find more variables, or the right variables for further studies.

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