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Evolution and inner structure of the polar layered deposits on Mars

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Polar layered deposits (PLD), Martian ice sheets, have long been thought to contain a record of the past climate. The inner structure and the evolution of the PLD is the subject of a number of controversial ideas, hypotheses and publications.

We consider a very simple scenario, in which the present-day PLD is a result of a history of H2O ice deposition and sublimation during some recent period of the geological history. The deposition - ablation balance (DAB) is a function of latitude. Typically, net deposition (DAB>0) occurs in the polar area inside some boundary latitude of zero balance, and net ablation occurs outside. This dividing latitude shifts back and forth due to climate change caused by the change of the spin/orbit parameters and availability of the water vapor source at lower latitudes. The outermost position of the DAB=0 boundary was well outside the present margins of the PLD; in the opposite extreme it could shrink to the pole. Through time such oscillations will produce a dome-shaped stack of deposits with a possible thin layer of deposits outside the dome and with a number of unconformities inside. These unconformities will have an east-west oriented strike and a very shallow dip.

There is a positive feedback between DAB and albedo: high albedo favors deposition, and fresh deposits have high albedo. With this feedback, when the climate system goes through oscillations, the boundary latitude between positive and negative DAB will stay for some periods of time at its outermost and innermost positions. This will result in steps in the generally domical shape of the PLD. When such steps are covered with later layers, unconformities with steeper dip, but still east-west strike are formed.

The DAB depends on surface slopes, because tilted surfaces are exposed to a smaller portion of cold sky, and equator-facing slopes receive greater insolation. Thus, for tilted surfaces, the DAB is shifted toward ablation. This is consistent with the fact that we see lower albedo in the present-day troughs, especially on their equator-facing walls. This slope effect causes formation of troughs at the places where the steps were formed due to the albedo feedback. The troughs eat away the steep-dip unconformities associated with the steps.

Simple climate-controlled balance of sublimation and ablation with albedo feedback and slope effect explains many characteristic properties of the PLD, namely: (1) the general dome-shaped PLD topography and thin outliers, (2) the presence of troughs and the general "shadow-like" character of their topography, (3) the shallow dip of the layers through the PLD (4) the identical section of layers within a single trough wall over long distances, (5) the absence of apparent unconformities on the trough walls over long distances, (6) non-identical sections of layers in neighboring troughs (7) the presence of identical segments of the sections of layers in neighboring troughs, (8) the character and location of rarely observed unconformities, (9) the albedo pattern of the PLD. Our very simple considerations do not explain some other characteristic features of the PLD, namely: (1) the brightness and textural signatures of the layers, (2) the spiral trough pattern, (3) the particular values of slope of trough walls and their latitudinal trend, (4) Chasma Boreale and similar features. Some additional processes and/or effects mist be considered to account for them.