What controls esker formation on the Canadian Prairies?

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ABSTRACT

Compared to the Canadian Shield, the Alberta prairie contains only a few, small eskers. Research has attributed this paucity to active ice sheet retreat, preferential development of canals rather than R-channels on deformable beds, and/or high permeability of substrate limiting the formation of R-channels. Based on their distribution, size, shape, morpho-sedimentary relationships and association with substrate, and topography we make several conclusions. (1) Esker pattern and the absence of systematic recessional moraines indicate that the hydrologic system recorded by eskers formed under regionally stagnant ice. (2) The presence of eskers on soft bedrock or fine-grained till contradicts the contention that R-channel drainage is precluded on a deformable substrate. (3) The association of large eskers, large lake basins and tunnel channels indicates that esker formation and preservation was facilitated by a ready sediment supply from antecedent tunnel channel fills and fans, hydraulic damming by glacial lakes or reservoirs, and decanting of meltwater from other lake basins. (4) Where an association with tunnel channels and large lakes is absent, the chaotic distribution/pattern and the prevalence of faulting and deformation within eskers indicate that eskers formed from short-lived and unstable R-channels.

BACKGROUND:

Compared to the Canadian Shield, the Canadian Prairies contain only a few, small eskers (red in Fig. 1) [1]. Research has attributed this paucity to preferential development of canals when drainage occurs over a deformable substrate and/or the high permeability of the clastic bedrock [2]. Both would inhibit the formation of R-channels necessary for esker development. The reversal of flow into deep aquifers supports this contention [3]. However, over 380 eskers exist in southern Alberta (red in Fig. 2). Therefore, the objective of this research is to evaluate the various controls on esker formation in this setting.

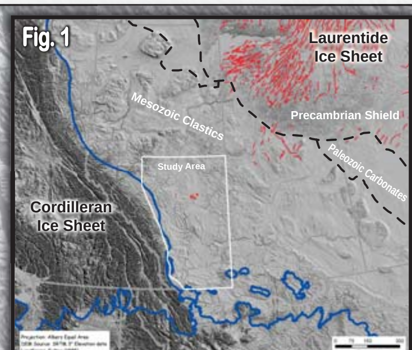

Fig. 1

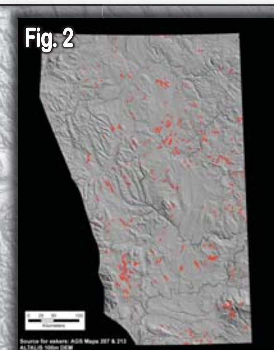

Fig. 2

DATA:

Alberta Geological Survey maps 207, 213 and 236 provided, in GIS format, bedrock and surficial geology. A DEM (100 m postings), provided by Altalis, was used for terrain analysis. Aerial photographs were used as a check on the GIS data. This check resulted in many "non-eskers" being deleted and a few unmapped eskers added. Ambiguous eskers were field checked. The resulting compilations are shown in Figs. 3 and 4.

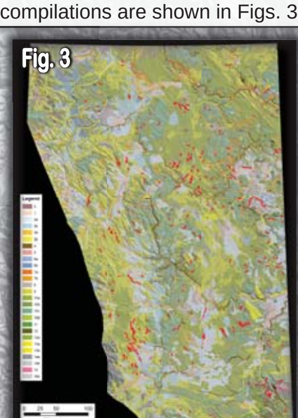

Fig. 3

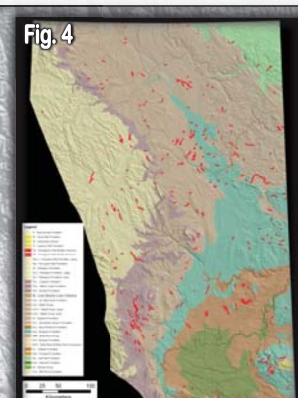

Fig. 4

DOES THE SUBSTRATE IMPACT ESKER LOCATION?

We performed multiple overlay analyses using the data in Figs. 3 & 4. These included using esker centroids and individual segments. Only the centroid analyses are presented (results are similar). The results were used to test the hypothesis that eskers have an expected occurrence based on the weighted areas of the substrate types. We used a chi-square analysis in conjunction with a Bonferroni z-statistic [4] to estimate if eskers occur more, or less, often in any substrate type. The Bonferroni adjustments were necessary when simultaneously estimating multiple substrate types and resulted in more appropriate confidence intervals. All analyses were significant at 90% confidence.

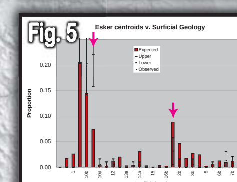

Fig. 5

The raw analysis for surficial geology indicates that the expected esker occurrence is significantly less than the observed for 10c (thick glaciogenic) and more for 2a (glaciolacustrine) (arrows) most notably.

The raw analysis for geology indicates that the expected occurrence is significantly less than the observed for the Willow Creek and more for Paskapoo formations (arrows).

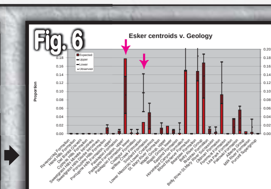

Fig. 6

Recognizing that the raw units did not accurately represent functionally similar substrates, we grouped the units into similar types. This involved removing surficial units that were demonstrably postglacial and grouping bedrock units into similar ages and paleoenvironments.

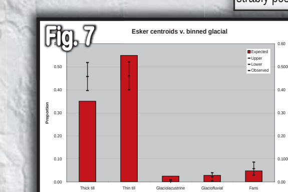

Fig. 7

The binned surficial units showed a markedly higher occurrence of eskers in those areas characterized by thick till. The opposite is true for those areas that have thin glacial material over bedrock.

As was evident in the raw analysis the occurrence of eskers in the Paskapoo (coarse-grained Tertiary sandstone) is lower than anticipated. The Willow and Scollard have more eskers than expected based on area.

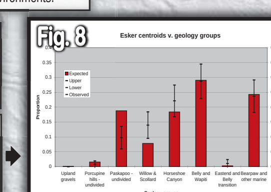

Fig. 8

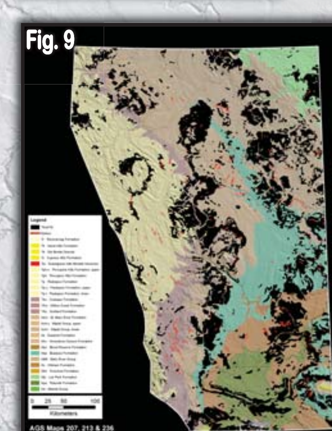

Fig. 9

Recognizing that the bedrock under thick till was likely not relevant to the operation of the eskers, we clipped out this area from the bedrock polygons. This operation was to ensure that we had not overestimated the importance of some bedrock substrate types. The result is the pattern of available bedrock (from esker perspective) (Fig 9). The results were not significantly different.

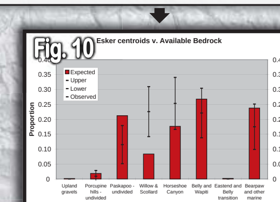

Fig. 10

These analyses indicate:

1. The contention that eskers should not form on a deformable substrate is not consistent with the data. In fact, eskers seem to preferentially form in areas of thick till.
2. The Paskapoo sandstone (a regional aquifer) does have fewer eskers than expected. This may indicate an important influence of substrate permeability.
3. The significantly higher number of observed eskers in the Willow & Scollard formations can not be explained by the impermeability of the bedrock. The Bearpaw formation is more impermeable and does not have higher proportion of eskers.

WHAT IS THE RELATIONSHIP WITH GLACIAL LAKES?

From preceding substrate analysis it is clear that there are other controls on esker location other than substrate. Two of the most likely controls are: (1) the supply of appropriately-sized sediment and (2) the presence of lakes that could maintain an open conduit during low flow periods [5] and provide water in the form of decanting flow between basins.

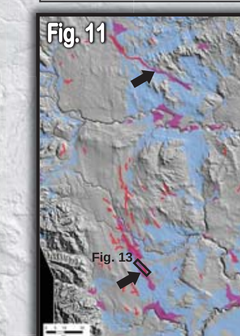

Fig. 11

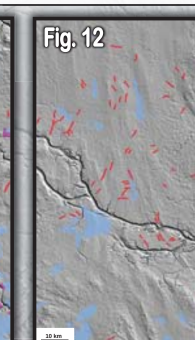

Fig. 12

Fig. 13

Fig. 14

Fig. 15

In a few locations in southern Alberta glacial lake basins are intimately linked to esker systems. In Fig. 11 two of the largest systems are located in channels and enter the lake basin (blue) through coarse fan sediments (purple). These fan sediments are clearly preexisting materials as the eskers are seen to truncate them (dotted line in Fig. 13) and directly overlie subtle bedrock depressions (Fig. 14). Given the relationship of these fan sediments to the channels that contain the eskers we interpret them as tunnel channel deposits. All large eskers in the area are associated with these sediments. Fig. 12 shows the situation where eskers are not linked to lakes. In these locations the eskers are short and do not have the crudely arborescent pattern that can exist (southern arrow in Fig. 11). In these upland settings the esker sediments are are usually deformed (Fig. 15) and there is an absence of terminal fans indicating short-term operation and removal lateral ice support.

CONCLUSIONS:

1. The analysis of esker location and their relationship with the substrate shows that the contention of [2] that eskers can not form in areas of thick till is not correct in the study area.
2. Where coarse-grained sandstone bedrock is close to the surface, eskers are rare. This may be the result of increased permeability and/or, more likely, a lack of appropriately sized sediment to be deposited and preserved.
3. The presence of tunnel channel fills and fans appear to provide the necessary sediment for the preservation of eskers.
4. Presence of upflow lakes to provide episodic inputs of water and sediment.

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