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Testing an Object-Oriented Method to Map Mid-scale Glaciated Landforms like Drumlin

Dr. Kakoli Saha

Drumlins are common elements of glaciated landscapes which can be easily identified by their distinct morphometric characteristics including shape, length/width ratio, elongation ratio, and uniform direction. To date, most researchers have mapped drumlins by tracing contours on maps, or through on-screen digitization directly on top of hillshaded digital elevation models (DEMs). The present study attempts to test object-oriented classification method available through Definiens Developer (V.7) to map drumlins. The Chautauqua drumlin field in Pennsylvania and upstate New York, USA has been chosen as a study area. As it is huge (about 2500 sq. km.), small test areas have been selected for initial testing of the method. The manually digitized polygons were imported into Definiens Developer as thematic vector layer and object-oriented classification was performed. Drumlin parameters were then extracted from polygons and used to compare the manual digitization method with automated object-oriented method. Statistically, there was high agreement between drumlin parameters extracted by the two different methods indicating that Definiens has the ability to extract the appropriate data in a meaningful way.

Drumlins are subglacially streamlined hills, roughly ovoid in shape, that contain glacial debris or bedrock. Through their shape and orientation, drumlins provide a wealth of information about the flow of the past glaciers. Collection of more and better data concerning drumlin morphology should therefore be helpful in providing information about past glacial processes and changes in subglacial environments over time and space (Knight, 1997). Researchers like Smith et al. (2006), Stokes and Clark (2003), Smith and Clark (2005), and Norton and Lanier (2007) have all used GIS techniques, mostly digitization and visualization to map drumlins. They simply digitized the drumlins manually in ArcMap either as smooth polygons (classical shaped drumlins) or as straight lines (spindle and mix of classical and spindle shaped drumlins). They then extracted shape parameters such as length, width, elongation ratio, area and perimeter from the manually mapped drumlins and used those to parameterize the drumlins. I would argue, however, that even though the research done is highly technical, the mapping undertaken by these researchers is still highly subjective.

As object-oriented classification method has never been tested on drumlins, or any other landforms that have patterns and occur in swarms, a simple test was undertaken. Could the object oriented method distinguish those polygons already digitized, and if so, could it then be used to extract statistics from the polygons that could be used to compare the manual digitization method with automated object-oriented method?

Study Area

The study area is the Chautauqua Drumlin Field, located south of Lake Erie in Pennsylvania and New York, USA (Fig. 1). The drumlin field is nearly 110 km NE-SW and 23 km NW-SE in width, covers an area of more than 2500 km2, and contains more than 750 drumlins, the majority of which occur on pre-existing upland surfaces that range in elevation from 350 to 630 m above sea level (Norton and Lanier, 2007). The drumlins in our study range from 328 m to 2831 m in length and from 140 m to 1000 m in width, and most are oriented close to the mean direction of 150°. The test area (Fig.1) was selected on the basis of higher drumlin concentration and covers a small portion of the drumlin field, south of Erie, Pennsylvania, in Erie County. The total area covered is 144 km^2.

Traditional Method of Mapping Drumlins

On-screen digitization is now, by far, the most popular method to delineate drumlins. For this digital topographical maps (DRGs) at a scale of 1:24,000 from Erie south, Hammett, Waterford,

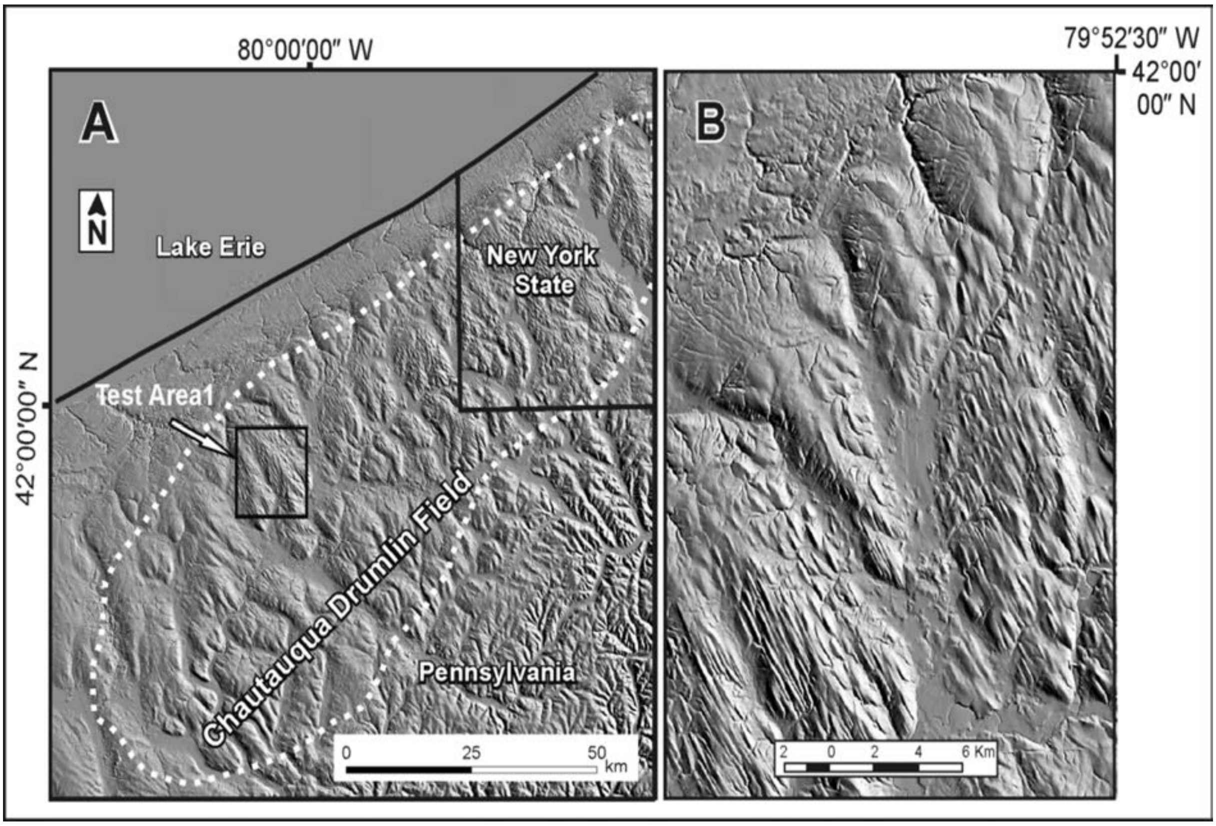

Fig. 1. A. Relief-shaded image showing location of Test Area in the Chautauqua Drumlin Field.
B. Closer look at the Test Area

and Cambridge Spring NE quadrangles were used (digital copies obtained from the Pennsylvania State University website- ftp://www.pasda.psu.edu/pub/pasda/). Drumlins in this test region were mapped in ArcMap by digitizing from Digital Raster Graphics (DRGs) following contour alignments. Smooth polygons were drawn at the bounding break of slope which is represented by at least three enclosed contours elongated from the NNW to SSE (Fig.2.A). This method had its own underlying problems: In this study area, drumlins are located on uplands which are highly incised; and drumlins in the area are closely spaced. As a result, it was difficult to locate the bounding break-of slope.

To address this problem, instead of working with just the DRGs, a decision was made to work on the DEM data itself. From the DEM the layers of slope and aspect were computed and subsequently merged with the raw DEM to make a 3-layer image. Slope is a calculation of the maximum rate of change across the surface from cell to cell in a gridded surface. Every cell in an output grid has a slope value. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain. For the test area the slope is calculated in degrees. Aspect identifies the steepest down slope direction on a surface. It can be thought of as slope direction or the compass direction a hill faces. It is usually measured clockwise in degrees from 0 (due north) to 360 (again due north, coming full circle). The value of each location in an aspect dataset indicates the direction of surface slope faces.

Slope and aspect data were merged with the raw DEM data. In the Merged Image (Figure 3 A), bounding break of slope is more defined than DRG. This Merged Image has been used along with DRGs to perform on-screen digitization in PCI Geomatica focus (Figure 3B). A total of 137 drumlin polygons were digitized and saved into a vector layer.

The resultant vector layer was then imported in ArcMap. The length (L) and width (W) were calculated from the digitized polygons by using the measuring tool available in ArcMap. Elongation ratio was calculated using length and width information (L/W). Area and perimeter were calculated using algorithms available in ArcGIS. All these data about

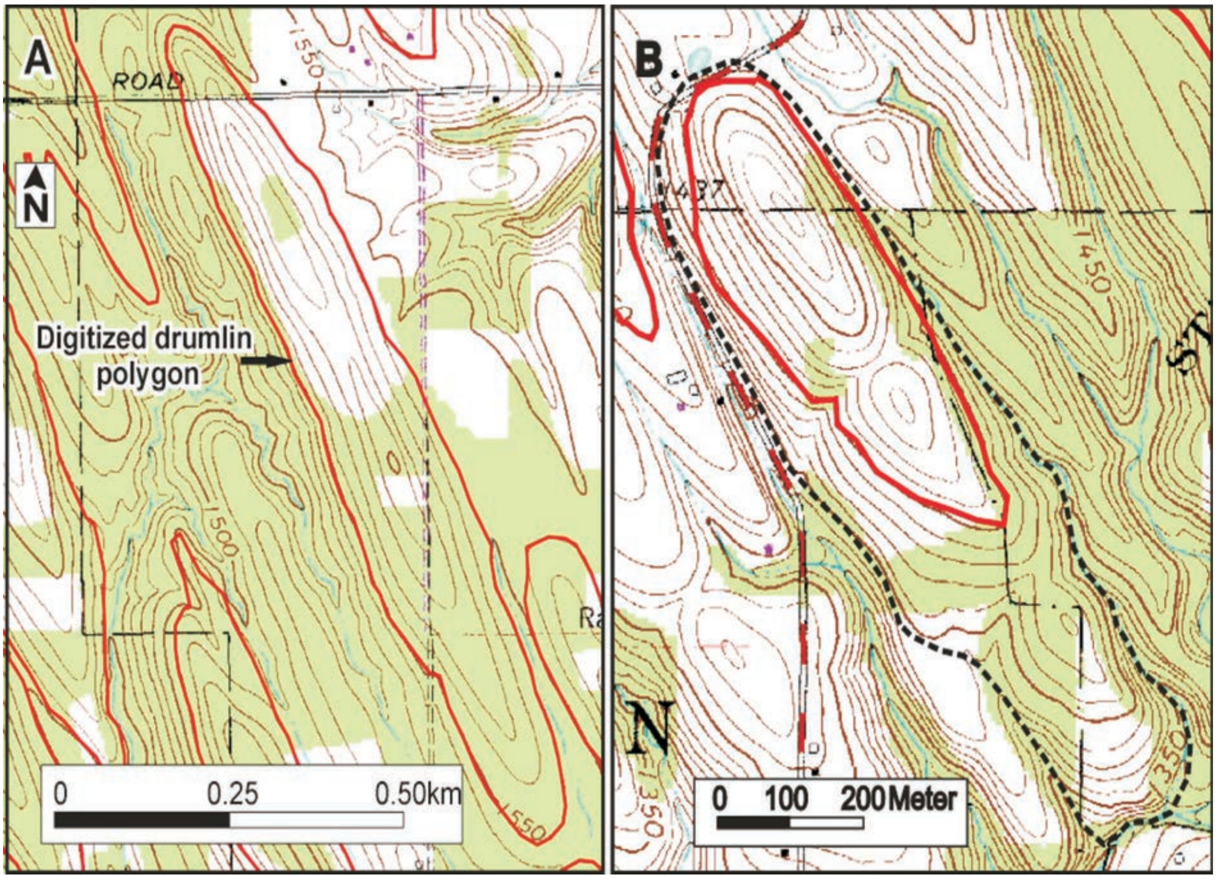

Fig. 2 A. Smooth drumlin polygon digitized in the ArcMap on the top of DRG,
B. The dilemma of choosing a drumlin boundary. Which one should be the actual size of the drumlin?
The red polygon or the black polygon? Both enclose distinct separate drumlin shapes.

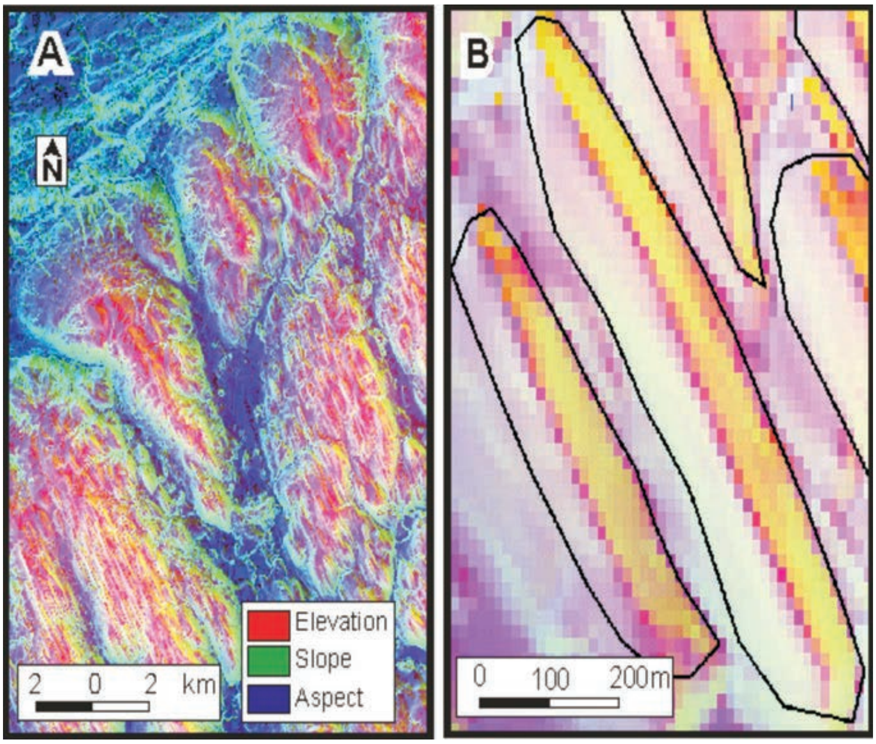

Fig. 3. A. Merge Image -RAW DEM, slope and aspect are overlaid on the top of each other;
B. Drumlins are digitized on Merge Image in PCI Geomatica

drumlin parameters were then recorded in attribute table along with the polygon layer.

Test of Object-oriented Method

The concept of object-based image analysis has been around since the early 1970s (De Kok et al., 1999), but implementation of the method lagged until the 1990s due to lack of computing power. Now, because of better computers and higher spatial resolution imagery, there is a renewed interest in object-oriented techniques. The major advantage of this approach is that it analyzes images in object space rather than in pixel space. Since drumlins are mid-scale glacial landforms which have a particular shape, size, context and texture, they can be extracted from DEM datasets as objects rather than aggregation of pixels. In addition, the object-oriented approach reduces the number of units (pixels versus objects) to be classified which also eliminates the "salt-and-pepper" effect common in per-pixel classifiers. Therefore, in short, this approach makes possible more robust classifications of drumlins. For this research, Definiens Developer (V.7) has been used to develop the object-oriented method. Definiens Developer is image analysis software produced and marketed by Definiens Imaging GmbH, Munchen, Germany. Definiens Developer implements the Fractal Net Evolution method in object extraction (Baatz and Schape,1999).

A new project is created in Definiens by loading the DEM data as the image layer and the digitized polygons as a thematic layer. The DEM in this case was just used as a backdrop and no additional information was used for subsequent analysis. Step 1 of image classification involved performing multi-resolution segmentation which is an unsupervised, knowledge free, bottom-up approach where single vectors are subsequently merged optimizing a homogeneity criterion (Definiens Developer, 2007). In Definiens's multi-resolution segmentation, the homogeneity criterion is used to determine which heterogeneity attributes of image objects are to be minimized as a result of a segmentation run. Two sets of criteria are used to describe image object heterogeneities: color-shape, smoothness-compactness. Color and shape must together add to 1. Also compactness and smoothness must add to 1 (Definiens Developer, 2007). In this particular segmentation, shape and compactness were given maximum emphasis (both of them set to 0.9) because the shape of the extracted image objects was already known (in this case they are digitized drumlin polygons).

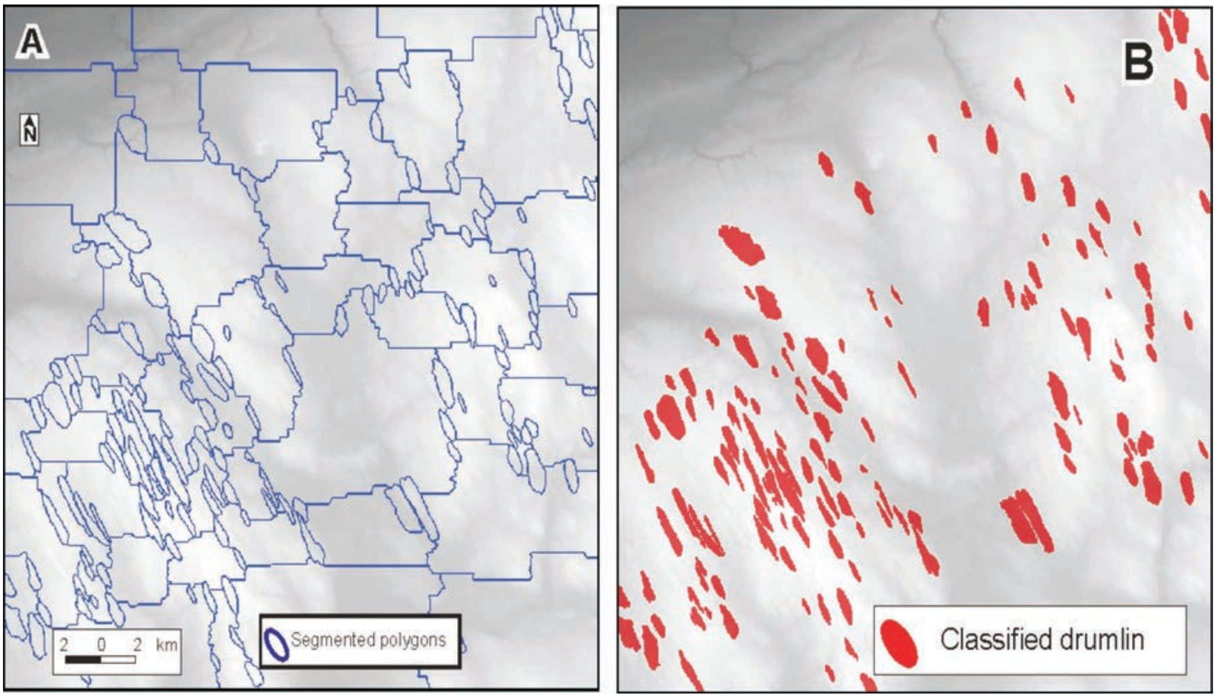

Fig. 4 A. Multiresolution Segmentation picked up the drumlin polygons from thematic layer.
B. Class Description Window showing defined criteria for "Drumlin" class.

Another parameter, scale, also needed to be set. The scale parameter determines the maximum allowed heterogeneity for the resulting image object. In this case the scale parameter was set high (200). Once image objects have been created, spectral, spatial and contextual information for each image object are obtained through the image object information window (Fig. 4A).

In Definiens Developer, basic classification algorithms analyze image objects according to defined criteria and assign each object to a class that best meets the defined criteria. To define the drumlin class main direction, length, width, elongation ratio and roundness were chosen. Figure 4B shows the classified image.

Extraction of Drumlin Morphometry

Post-classification, the same set of drumlin parameters that were derived from the manually digitized drumlins (length, width, elongation ratio, area, and perimeter) were obtained in Definiens Developer. The two sets of data were then compared statistically.

(a) *Statistical Comparison of the two Methods*

The objective behind the comparison is how well the population identified by Definiens compares with the manually identified population. For this, the principal parameters for the 137 closely matched drumlins extracted through two different techniques were compared. In all cases, the means for the Definiens derived data set were larger except for the elongation ratio (Table 1).

The significance of the differences between the two sets of results was evaluated with the nonparametric Mann–Whitney–Wilcoxon test (Table 2). This test was used in preference to the Student t, because the later assumes Gaussian distributions and a battery of tests (the rightmost four columns in Table 1) showed that the parameters mostly failed normality in skewness, kurtosis, and overall distribution. The test results (Table 2) show that only length-width ratio and width were statistically different. But, the difference is minor, so we could be justified in ignoring all the differences.

Table 1: Summary Statistics and Test of Normality

Parameter	Software	Mean	Standard Deviation	Max.	Min.	Kolm.-Smirnov	Chi^2	Gr. Skew.	Gr. Kurt.
Length (m)	ArcMap	921.9	405.7	2505.1	285.3	nn	nn	nn	nn
	Definiens	943.7	414.2	2519.8	280.4	nn	nn	nn	nn
Width (m)	ArcMap	265.9	118.6	716.7	89.0	N	nn	nn	nn
	Definiens	327.6	124.4	807.5	140.2	N	nn	nn	nn
L / W	ArcMap	3.82	1.88	10.21	1.93	nn	nn	nn	nn
	Definiens	2.99	1.17	7.55	1.4	nn	nn	nn	nn
Area (hectare)	ArcMap	20.9	15.3	95.6	2.3	nn	nn	nn	nn
	Definiens	22.4	16.0	99.1	2.8	nn	nn	nn	nn
Perimeter (m)	ArcMap	2132.4	909.8	5721.5	685.4	N	nn	nn	nn
	Definiens	2190.5	906.8	5550.3	702.6	N	nn	nn	nn

The tests for normality are the Kolmogorov-Smirnov test, a five-cell chi-square comparison against a normal population, and Griffiths' tests for for nonnormality in skewness and kurtosis. G means Gaussian (normal), nn = non-normal, and nnn = nearly non-normal. (The switch from upper-case and G to lowercase and n is simply to enhance legibility.)

Table 2: Mann-Whitney-Wilcoxon test

	Z score for U score	P diff > 0.90	MWW Decision
Length, m	0.31	0.39	Same
Width, m	4.58	1.00	Different
L / W	4.25	1.00	Different
Area, hectare	0.996	0.68	Same
Perimeter, m	0.68	0.50	Same

P diff = probability of the two data sets being different The Mann-Whitney-Wilcoxon test is used inpreference to a Student's t test because the data are non-gaussian. The Z score column reports the Z score associated with the Mann-Whitney-Wilcoxen U value. The second column reports the probability associated with that Z score that the ArcMap and Definiens samples are different, and the third column simply expresses that decision in common English, using a critical value of 0.90. The Chi-square column gives the probability of difference according to a less sensitive five-cell chi-square comparison based on cell limits at ± 0.5 standard deviations, ± 1.5 standard deviations, and beyond ±1.5.

Conclusion

The main objective of this research is to determine if the object-oriented method would even work on already mapped polygons. Interestingly, all the parameters except elongation ratio showed a higher mean value than the ArcMap polygons. Statistically, there was high agreement between drumlin parameters extracted by the two different methods indicating that Definiens has the ability to extract the appropriate data in a meaningful way. The success of this research broadens the scope of building an automated method where object-oriented classification can automatically extract drumlins from DEM. Hence, the objectivity of manual mapping can be avoided.

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References

1. Baatz, M., and A. Schäpe (1999): Object-Oriented and Multi-Scale Image Analysis in Semantic Networks. The 2nd International Symposium: Operationalization of Remote Sensing, New Methodologies,16-20 August 1999, ITC, NL.
2. Definiens Developer 7 (2007a): Userguide. München, Germany: Definiens AG.
3. De Kok, R., T. Schneider, and U. Ammer (1999): Object based classification and applications in the alpine forest environment. In Fusion of sensor data, knowledge sources and algorithms. International of Archives Photogrammetry and Remote Sensing 32, 7-4-3 W6.
4. Kinght, J.(1997): Morphological and morphometric analyses of drumlin bedforms in the Omagh basin, north central Ireland. Geografiska Annalerno. Series A 79(4):255-266.
5. Norton, K. P., and A. J. Lanier (2007): Subglacial landforms of the Erie uplands, northwest Pennsylvania: implications for early Wisconsinan glacial chronology of the Erie lobe of the Laurentide ice sheet. Journal of Pennsylvania Academy of Scienceno. 81:20-30.
6. Smith, M. J., and C. D. Clark (2005): Methods for the visualization od digital elevation models for landform mapping. Earth Surface Processes and Landforms 30, 885-900.
7. Smith, M. J., J. Rose, and S. Booth (2006): Geomorphological mapping of glacial landforms from remotely sensed data: An evaluation of the principal data sources and an assessment of their quality. Geomorphology 76, 148-165.
8. Stokes, C. R., and C. D. Clark (2003): Giant glacial grooves detected on Landsat ETM+ satellite imagery. International journal of Remote Sensing 24, No. 5:905-910.