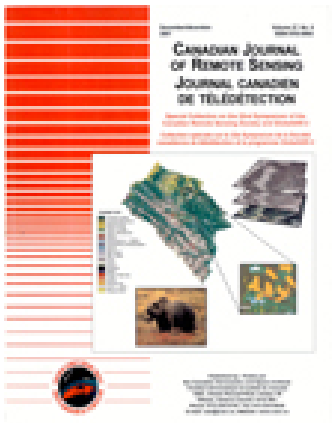

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Research Note • Note de recherche

Combined Use of RADARSAT-1 and Landsat TM Data for Geomorphological Applications in Lowlands of Buenos Aires Province, Argentina

by G.A. Martínez • J.M. Arca • Q.H.J. Gwyn • M.V. Bernasconi

RÉSUMÉ

L'objectif principal de cette recherche est de générer une information pour modéliser la géomorphologie actuelle et ancienne de la région. Les techniques d'analyse d'images constituent l'un des meilleurs outils pour la cartographie géomorphologique dans la région étant donné que les principales formes de terrain (paléodunes et caractéristiques de drainage) sont peu visibles sur le terrain en raison du faible relief et du couvert herbeux dense. Des images RADARSAT-1 en mode faisceau 2 large ont été fusionnées avec une image Landsat TM. Trois grandes unités géomorphologiques ont été différenciées : la chaîne Tandilia, la frange éolienne (marginale par rapport à la chaîne Tandilia) et la plaine fluvio-éolienne. Les meilleurs résultats ont été obtenus par l'intégration d'images RADARSAT-1 durant les périodes sèches et de l'image Landsat durant les périodes humides, spécialement dans la plaine fluvio-éolienne. La zone correspond à une topographie de relief très plat (pente<1%) caractérisé par des dunes longitudinales et paraboliques silteuses et des cuvettes de déflation et des lunettes associées. Un système de drainage constitué de rigoles sous-parallèles courtes est superposé à la topographie relique. Les formes éoliennes de terrain n'avaient jamais été décelées avant que ces images ne soient analysées grâce au contraste entre la topographie et l'humidité du sol qui apporte une information plus détaillée. Les données Landsat TM ont fourni une information utile sur l'utilisation du sol alors que les formes géomorphologiques ne pouvaient être reconnues que sur les images RADARSAT.

SUMMARY

The main objective of this research is to generate information to model the present and past geomorphology of the area. Image analysis techniques are among the best tools for geomorphological mapping in the area, since the main landforms (paleodunes and drainage features) are barely visible on the ground because of their low relief and dense grass cover. Wide Swath Mode Beam W2 RADARSAT-1 images were fused with a Landsat TM image. Three main geomorphic units were differentiated: Tandilia Range, Aeolian Fringe (marginal to the Tandilia Range) and the Fluvio-Aeolian Plain. Best results were obtained from the integration of RADARSAT-1 during dry periods and Landsat data during wet periods, especially in the Fluvio-aeolian Plain. It corresponds to a landscape of very low relief (slope<1%) characterized by longitudinal and parabolic silt dunes and linked deflation ponds and lunettes. A drainage system made up of short subparallel streams is superimposed on the relic landscape. The aeolian landforms had never been recognized until these images were analyzed because of the topographic and soil moisture contrasts, which provide the most detailed information. The Landsat TM data provide excellent information concerning land use, however the geomorphologic landforms were only recognized on the RADARSAT images.

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Introduction

The lack of basic studies such as geomorphological maps has greatly hampered land-use planning and soil mapping in the Pampas-dominated province of Buenos Aires in east central Argentina. The absence of adequate information concerning factors controlling surficial hydrology has resulted in serious problems related to flooding, a constant geohazard in the Pampas (Martínez, 1997). Furthermore, the absence of geomorphological maps means that the interpretation of soil maps has been significantly impaired.

The main objective of this paper is to present an evaluation of RADARSAT-1 coupled with Landsat TM data to create geomorphological maps. Specifically we have evaluated satellite data to provide information concerning the geomorphology of the study area. The resulting geomorphological scheme is regional in nature because it is dominated by aeolian processes, therefore it is one that can be applied to the entire province of Buenos Aires.

The study of ancient landforms as well as the environmental conditions and spatial variability that took place in late Quaternary and early Holocene periods are valuable and essential evidence for the reconstruction of the landscape. Knowledge of the soil-geomorphology relationship provides information and criteria in order to produce better land-use planning maps regarding specific requirements of a productive agricultural system.

Geomorphological Setting

The study area lies in the southeastern part of the Buenos Aires province (37.5-38.5°S, 57.5-58.5°W) (**Figure 1**). Based on Landsat MSS results from the late 1980s, a very small-scale geomorphological map was prepared by Malagnino (1988) (**Figure 1**). The map shows the distribution of longitudinal dunes that are the dominant landform. They range in length from tens to hundreds of kilometres. Other maps derived from air photos in the southeastern part of the province could not provide a synoptic view; thus the mega-aeolian landforms were not described. Striking east-west through the study area is a range of low hills (300 m) consisting of a group of table-like hills with flat summits. Known as the Tandilia Range, they are composed of subhorizontal quartzite strata of Balcarce Fm of Lower Paleozoic age (Dalla Salda *et al.*, 1979). Mantling the entire region are Late Cenozoic sediments composed by eolian silt (loess) of volcaniclastic origin (Teruggi, 1957; Tricart, 1973). Based on mineralogical data, they were derived from the Andean region about 1100 km to the west.

Methodology

Images include RADARSAT Wide Mode descending pass (W2, approximately 22 to 27 m ground resolution, March 17, 1998) and Landsat TM (approximately 30 m resolution) data from August 3, 1998 (**Figure 2**). Image processing included georeferencing, image enhancements and integration tasks. For georeferencing, the image to map (1:50 000) method was chosen. A series of ground control points were located on the image and registration was performed with cubic convolution and second-order polynomial transformation. A similar process was applied to the TM images, but in this case nearest-neighbour and a second-order polynomial transform were used. A variety of false colour images were created by fusing the colour component of TM bands 3, 4 and 5, with the intensity component of a RADARSAT image through a transformation of the colour space (RGB→IHS→RGB) (Harris *et al.*, 1994). This product was used for preliminary visual analysis. Band combination with TM and RADARSAT was applied. Statistics between bands was performed and the coefficient of correlation calculated. Principal component analysis was made on the TM bands and W2 radar image.

Results and Discussion

Neither the high spatial resolution Fine Mode (Beams F2 and F4) nor the Wide Mode (Beam W2) imagery taken during the wet season gave visually effective results for geomorphological mapping at small scale. Best results among the RADARSAT-1 images were achieved with acquisitions during the dry season in the lowlands. Furthermore, images with illumination at oblique angles to the eolian features gave the best results. This suggests two important physical features about the remote sensing of the paleodunes. First, soil moisture plays an important role in the identification of the longitudinal dunes. This is based on the fact that the dry season images present higher contrast than do the images taken in the wet season, as is established above. Second, the relief of the dunes, which only rise 0.5 to 3 metres above the surrounding plains, is another important component in the backscatter mechanism.

While eolian features (paleodunes) are most distinguishable in RADARSAT-1 images, fluvial features are more easily mapped from Landsat TM images (**Figure 3**). For this reason alone, data integration (SAR and optical) can greatly improve the analysis and geomorphic interpretation of the imagery.

There are two main thematic results: definition of three principal geomorphological units and the identification of three sets of paleodunes. Mapping of the geomorphological units and the dunes was only possible because of the availability of the satellite imagery. **Figure 3** shows the three main geomorphic environments: Tandilia Range, Aeolian Fringe and Fluvio-Aeolian Plain. The Aeolian Fringe comprises the areas between the foot of the Range and extends down to the 60-metre contour line (**Figure 3**). It is characterized by a system of hills up to 60 metres high with a complex morphology. These elevations either occupy the valleys or are situated against the ranges. The lower limit is clearly defined on the combined RADARSAT-1 and Landsat TM composite, where the abrupt change in morphology is evident (**Figure 3**). The surficial deposits of the Aeolian Fringe are loess that provides a rich soil for intensive cropping. The limit is defined in the images by dramatic changes in land use and differences in contrast. The Fluvio-Aeolian Plain extends approximately from the 60-metre contour line down to sea level. This unit occurs in a landscape of very low relief (slope < 1%) characterized by longitudinal and parabolic silty dunes and deflation ponds (**Figure 3**).

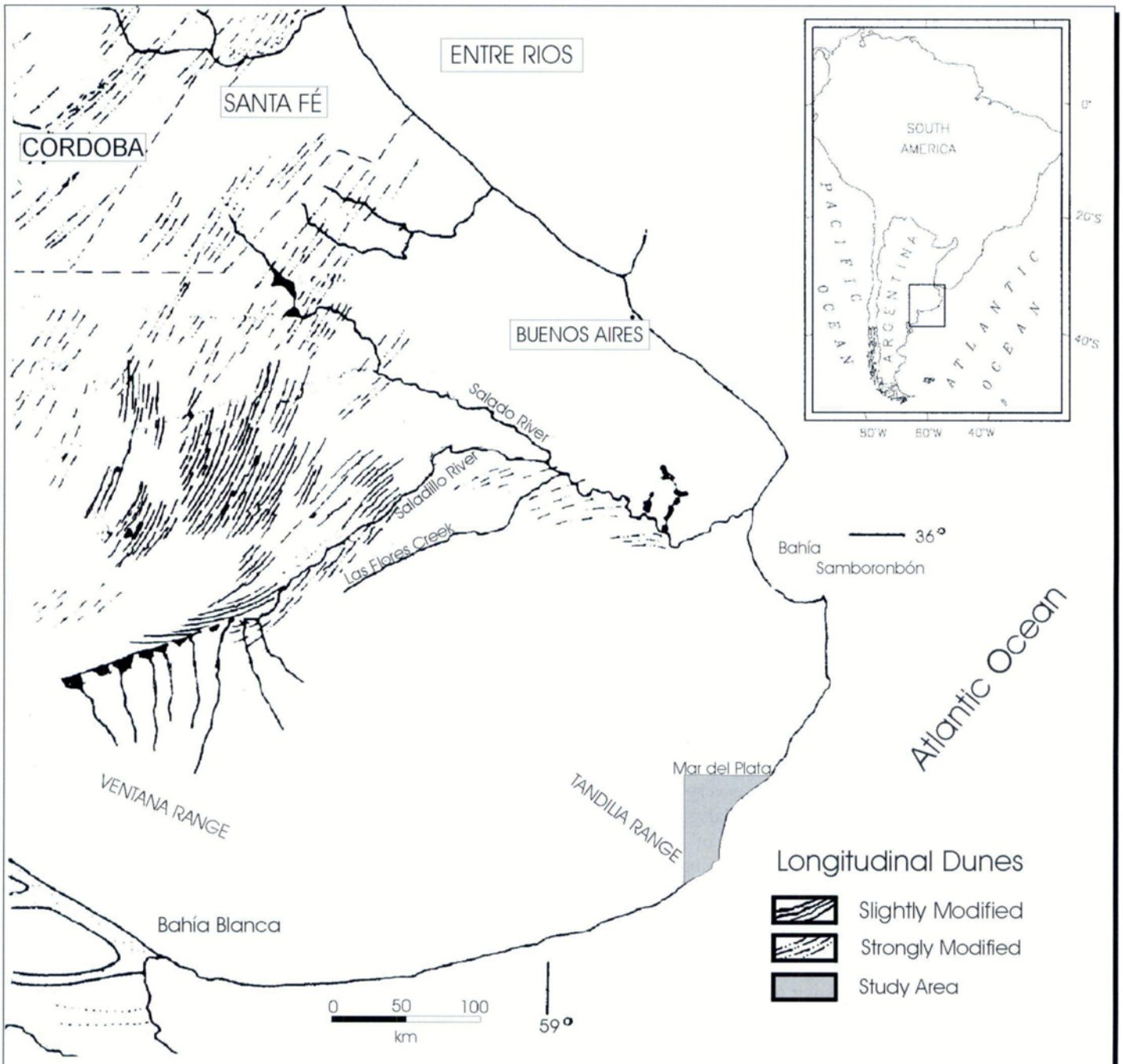

Figure 1.
Location map of Buenos Aires Province and the study area surrounding Mar del Plata. Geomorphological map of the Province of Buenos Aires modified after Malagnino (1988).

Because of their low local relief and dense grass cover, paleodunes and drainage features are generally not recognizable on the ground. Indeed, neither the soil maps nor land-use maps have ever included these landforms in the past. A drainage system made up of short subparallel streams is superimposed on the relic landscape.

The analysis of RADARSAT-1 images allows us to recognize landforms of eolian origin which could not be recognized from Landsat images (MSS and TM). This can best be seen in the Fluvio-Aeolian Plain geomorphic unit, which includes an assemblage of longitudinal and parabolic silty dunes and deflation ponds (**Figures 3** and **4**). The first set corresponds to a prior eolian cycle, with an average direction of N45°E and is composed entirely of parabolic dunes. The second one has a direction N82°E, and cross-cuts the first set (**Figures 3**, **4** and **5**) integrated by longitudinal and megaparabolic dunes. Parabolic and linear dunes are strongly related to unimodal winds, thus these dunes were due to paleowinds blowing from the SW and W respectively. The dune's length ranges between 4 and 30 km, widths range from 40 to 380 metres, while their height ranges

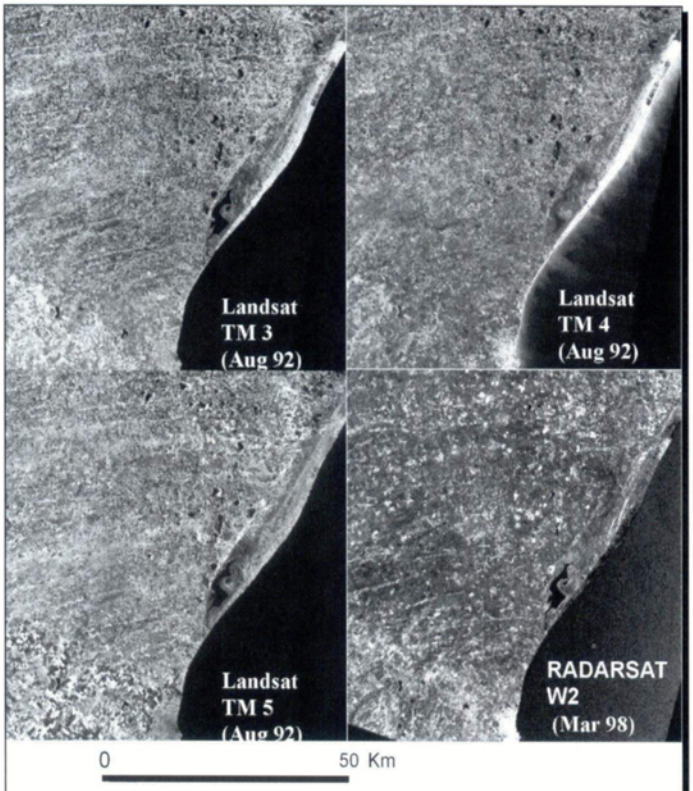

Figure 2.
Four separate images including Landsat TM 3, 4, 5 and RADARSAT-1 W2. The linear features on the TM bands are related to the land use and on the W2 image are related to the local topography and soil moisture contrasts within paleodunes.

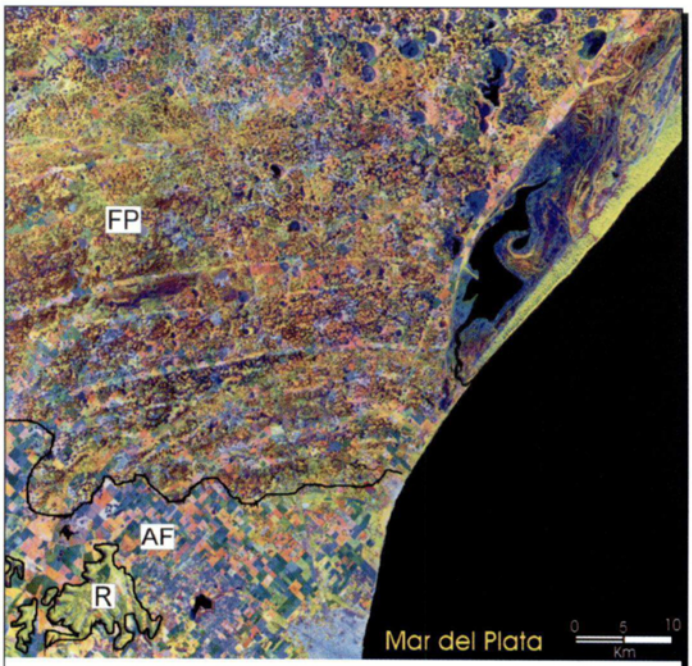

Figure 3.
RADARSAT-1 W2 and TM 3 and 4 in a composite image of the study area. The Tandila Range (R) and the Aeolian Fringe (AF) are visible in the southwest corner. Fluvio-Aeolean Plain (FP) covers most of the image, paleodunes are pale linear features and the loess plains shown as areas of mixed land use.

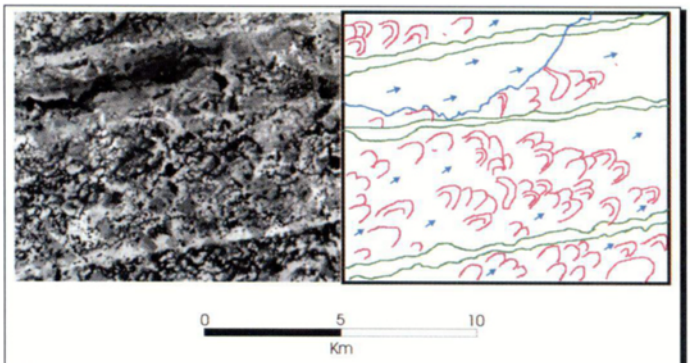

Figure 4.
RADARSAT-1 W2 image. First set of parabolic dunes (dark curvilinear) in red colour. Second set (light straight lineaments) composed by longitudinal and megaparabolic dunes in green colour.

from 0.5 to 3 metres. This extensive dune field, now completely vegetated and inactive, must have been active as recently as the last full glacial and Holocene stadial events. Intervals of more active loess transport may be correlated with periods of dune formation (**Figure 5**). Thus, the modern landscape reflects not only the present climate but also several paleoclimates.

Conclusion

RADARSAT images have formed the basis of a complete geomorphological interpretation of the Pampas area of Buenos Aires province for the first time. The dunes and aeolian deposits have physical and topographic characteristics which are subtle but have a distinct impact on the backscatter mechanisms of spatial variations in moisture content and also low local topographic relief. Combined with the sensitivity of Landsat optical data to land use and land cover, the integrated images allowed the development of a new insight into the soil-geomorphology relationship. Not only do the relic landforms (dunes and loess plains) have a direct influence on land use patterns, but also they are a control on surface drainage patterns, thereby affecting the distribution of floods in the interdune areas. In the next phases of this research, we will extend the mapping to cover priority areas for land planning and land management. Of crucial interest are the areas subject to periodic flooding in which land use and land development have not benefited from an understanding of the geomorphological processes.

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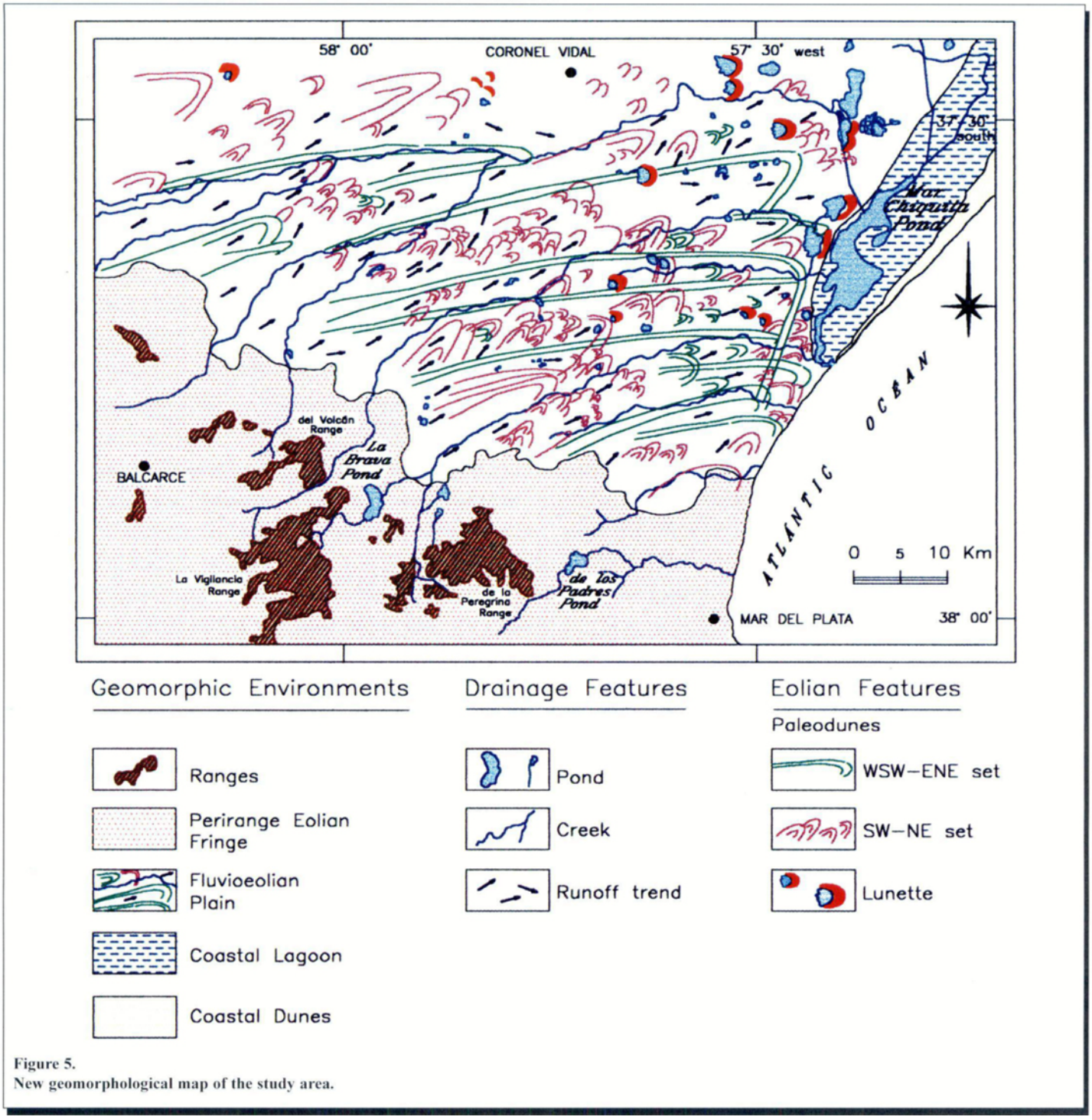

Figure 5.
New geomorphological map of the study area.

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