TOWARDS AUTOMATING THE PRODUCTION OF SOIL SURVEY MAPS
(Extended Abstract)

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ABSTRACT

Soil survey involves the study of soil characteristics in order to predict exploitable properties. For example, predictions may be made as to the most viable crops or the best scheduling of seasonal activities. The results of the detailed soil survey, and of the predictions, are presented as a series of maps. Producing soil survey maps is labour intensive and uses highly skilled soil scientists who sample the soil in the survey region and deduce boundaries between soil types, often sketching these during the survey.

This paper describes a project whose objectives are; firstly, to make the process of map production less reliant on the availability of highly qualified personnel; secondly to remove some error-prone manual processes; and thirdly, to make the results of expensive surveys more widely available.

The approach described attempts to assist the production of maps by automating the analysis of the original survey data. The process uses the Voronoi tessellations of the point survey data as a convenient data structure. An approximation to the detailed soil map is then derived directly by combining this information with the other data for the region. It is the efficient performance of this combination step which is the principle goal of the current phase of the project. The paper concludes by describing the remaining problems and future directions for the work.

Keywords: Soil Survey, Cartography, Computer Aided Mapping, Voronoi Tessellations, Thiessen Polygons, Dirichlet Regions

Background

A soil survey involves the detailed study of the soil types and characteristics over the survey region in order to be able to predict various exploitable properties. For example, results might indicate the most viable crops, the best strategy for soil management (e.g. scheduling of seasonal activities), and the suitability for particular developments (e.g. irrigation). These results are produced as a number of thematic maps showing individual aspects. For example, figure 1 shows a sample from a map displaying the suitability of the ground for irrigation.

The trial survey data used for this project has been derived from a recent survey of part of the Argos plain in Greece, undertaken by the Greek Government as part of a project funded by the Food and Agriculture Organisation of the UN [3]. For this survey maps are produced manually. The soil is first sampled at a large number of points (figure 2) and the findings at these points used to define regions of constant soil type on detailed soil survey maps (figure 3). The raw data for one map sheet consists of approximately 5000 sample points plus those topographic features which will appear on the map. Each sample point is encoded to show the classification of various attributes recorded in the field (e.g. figure 4). As can be seen from the sample in figure 3 the detailed soil map consists essentially of a polygon mosaic where each polygon boundary delimits an area of constant soil type. These polygon boundaries are defined in one of two ways:-

(1) The surveyor in the field records point data plotted as shown in figure 2, which the cartographer then analyses, drawing boundaries around regions where all the samples share the same classification.
(2) The surveyor may plot the boundaries directly, as in, for example, recording a boundary where the slope changes.

The final components of the detailed soil map are the topological features such as towns, rivers and roads, which are derived from standard maps and/or aerial photographs.

Thematic maps are produced from the detailed soil map by amalgamating adjacent polygons in the mosaic where the differences between the detailed soil classifications of the polygons are not significant within the classifications of the theme being mapped. The successful production of a suitable detailed soil survey map is thus the first stage in any automated system for thematic map production.

The first phase of this work (reported in [2]) was directed at simulating the way in which the first category of polygon boundary above was generated from the detailed point data. For this category of polygon, each point is being used to define an area of influence and, if sample points are of equal significance, the areas defined by the points are given by their Voronoi tessellations. The pilot system therefore constructed the Voronoi tessellations and amalgamated adjacent tiles of the same classification to produce an approximate detailed soil map for this type of data. Topological features were then overlaid and a variety of output formats considered (e.g. figure 5). Colour output has also been produced, but is not included here due to problems of reproduction [2].

Progress in the Project's Second Phase

At the end of the first phase there were still a number of factors not fully integrated in the production of the detailed soil map:-

(1) There had been no attempt to combine polygons not generated from the point data into a combined polygon mosaic.
(2) The choice of shadings and colours used for map display were chosen at random, rather than using an algorithm to reflect the properties of the soil type.
(3) No attempt had been made to associate the extra detailed information from soil profiles, hydraulic conductivity and water infiltration tests with the rather cruder soil samples.

By the end of the second phase it is intended that all of these problems will have been tackled, but at present the most progress has been in the first area with some effort and ideas for the other two areas. The primary problem is the definition of suitable algorithms to merge the polygon mosaic defined by the surveyor in the field (e.g. for hilly soils) with the mosaic of Voronoi tiles produced from the point survey results.

Four approaches for this step have been or are being considered, as follows:-

(1) An adaption of Green and Sibson's method [6] for computing the Voronoi tessellations of the point data, so that the tessellations are computed within an arbitrary closed polygonal boundary, which may include holes, rather than the current implementation which uses a rectangular outer boundary.
(2) An incremental vector based technique for amalgamating a complete mosaic of Voronoi tiles, computed using a rectangular boundary as at present, with a polygon mesh digitised from the field survey.
(3) The use of temporal priority (i.e. the order of painting the polygons on raster displays) to produce merged raster images without ever computing areas of overlap and positions of intersections.
(4) The most promising method is a development of method (3) first proposed by Earl [7,8]. In this technique the edges of the two complete polygon mosaics are first drawn into single bit overlay planes in a frame buffer. These overlay planes are then scanned sequentially and points of intersection detected where the bits are set in both overlay planes. The practical problems of implementing this conceptually simple algorithm will be discussed.

It is apparent that these techniques can be applied for all the polygon mosaic work not covered by the first phase of the project. In addition to the problem of merging the polygon mosaics, some experiments are being carried out using the algorithmic generation of colour and texture to try and reflect the various soil types. When applied to detailed soil maps the number of parameters appears to prohibit a simplistic mapping of properties to colours, but it is however possible to invent reasonable algorithms for use with the thematic maps.

The use of the detailed soil profiles and the results of other tests is based partly on proximity to the point of testing and partly on the soil type of the samples where the detailed test was made. The incorporation of this data will therefore use proximity calculations, aided by the Voronoi tessellation work of the earlier stages of the project, combined with keyed cross referencing, via the soil classification, based on more traditional database techniques.

Further Work

Whilst considerable progress has been made, it is obvious that there are several topics which must be addressed before these methods could be applied in a production system. Amongst these are:-

(1) Efficient handling of the large volumes of data involved in real surveys.
(2) Design of a suitable query language for accessing a database of stored maps and analysis results. Early work has already been done on some aspects of this [5].
(3) Related to (2) is the more generalised problem of the definition of the classification schemes used to define thematic maps and the mapping symbols used to represent them.
(4) Effective and user-friendly interfaces for all aspects of the system, from data entry and checking to map specification and production.

Acknowledgements

This project has drawn on the activities of several groups. The inspiration for the project came from discussions with Professor N. Yassoglou and Dr. V. Kollias of the Athens School of Agriculture and thanks are due to them for the ready supply of 'real' data. The contributions of members of the Geography Algorithms Group [9] is acknowledged, and in particular Dr. Wendy Milne's efforts in helping to develop the system described here. Colin Titcombe, also of the GAG project developed the implementation of Green and Sibson's algorithm for computing the Voronoi tessellations, and the Computational Geometry Project, headed by Professor A.R. Forrest, developed the Grinnell graphics library [10] used for the colour output. GINO-F was used for all the remaining graphics.

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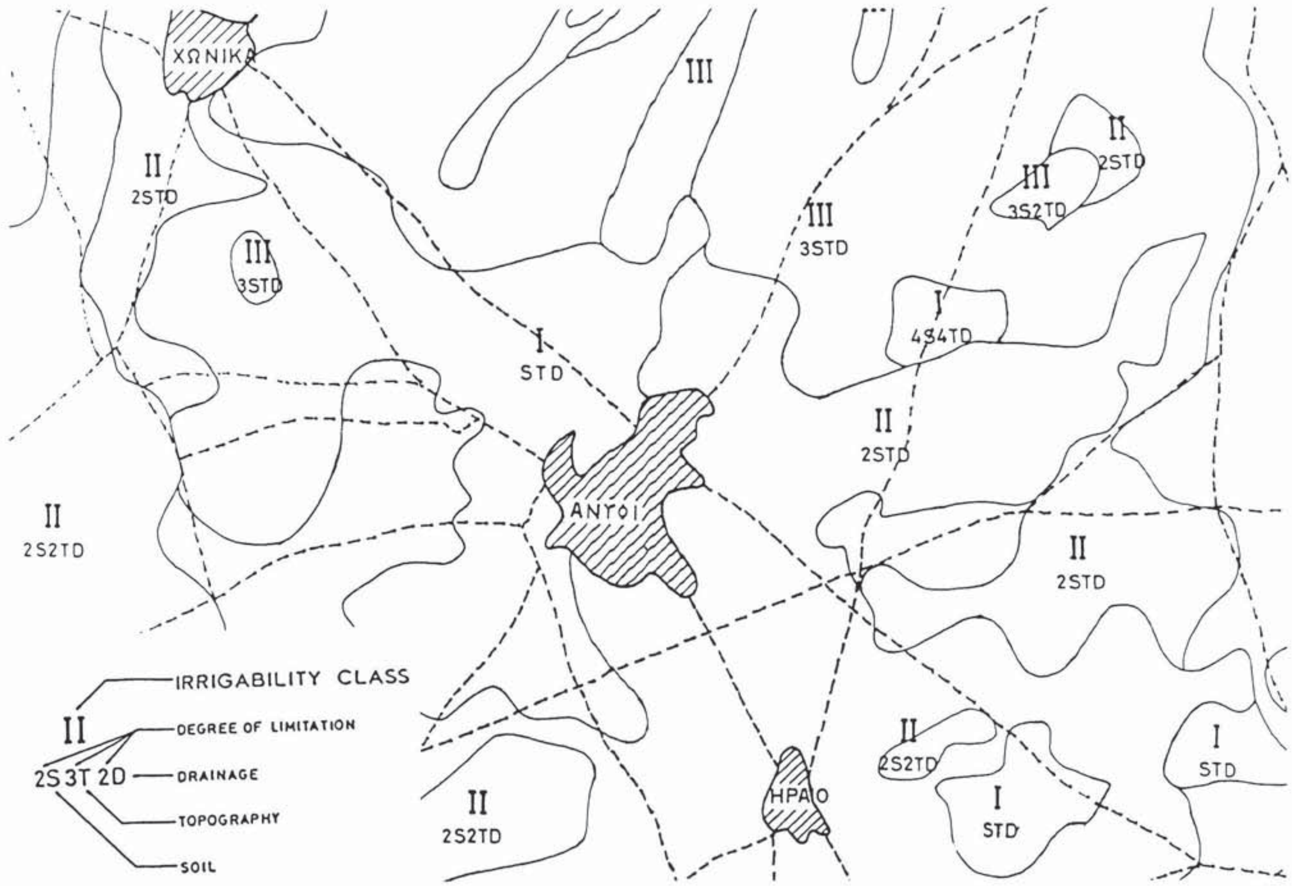

Figure 1 Irrigibility Map for part of the Argos Plain

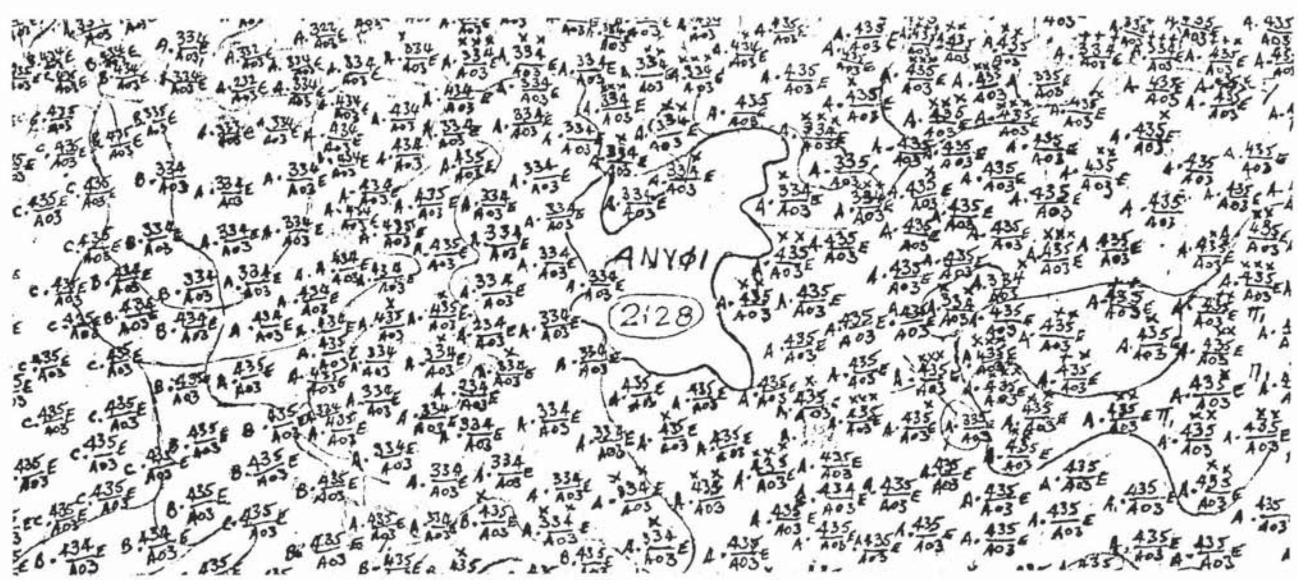

Figure 2 Sample data for part of the same survey

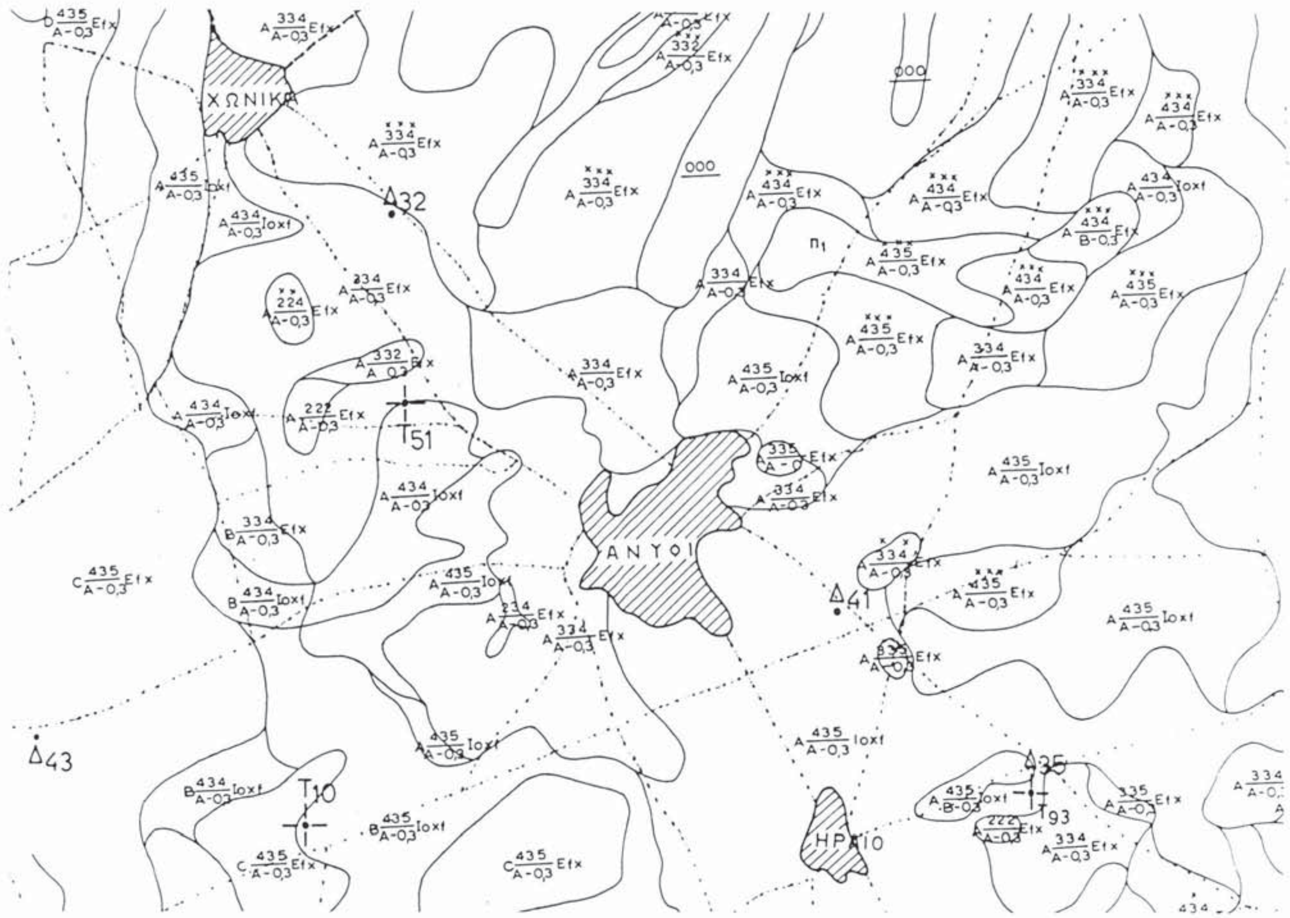

Figure 3 Detailed Soil Map for the Same Region

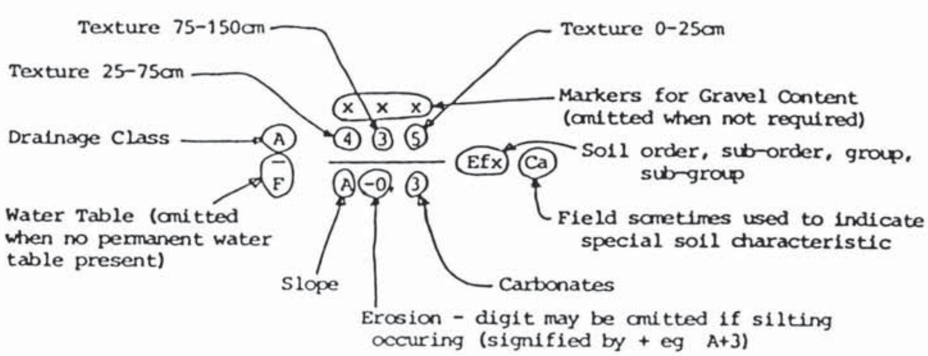

Figure 4 Sample of Classification Scheme Used for Soils

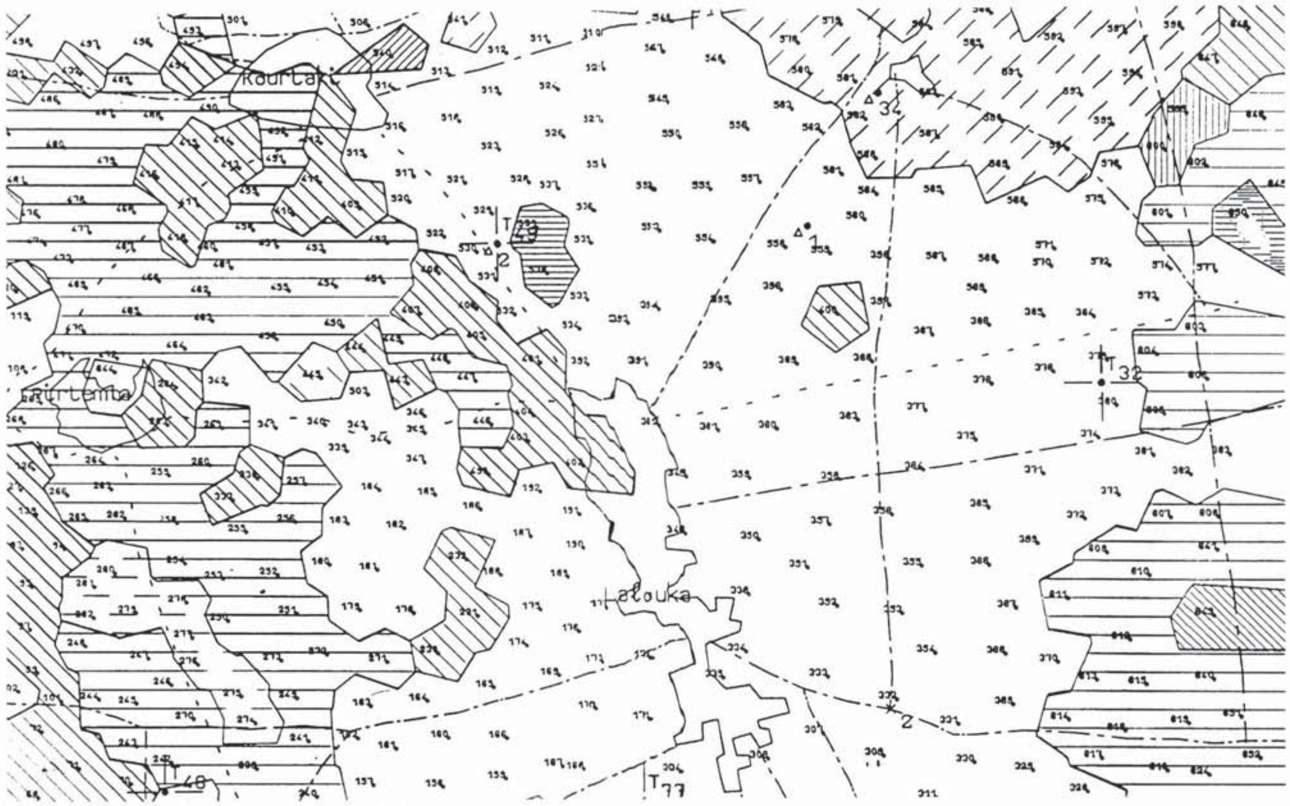

Figure 5(a) Check plot of data points combined with computer generated soil polygons

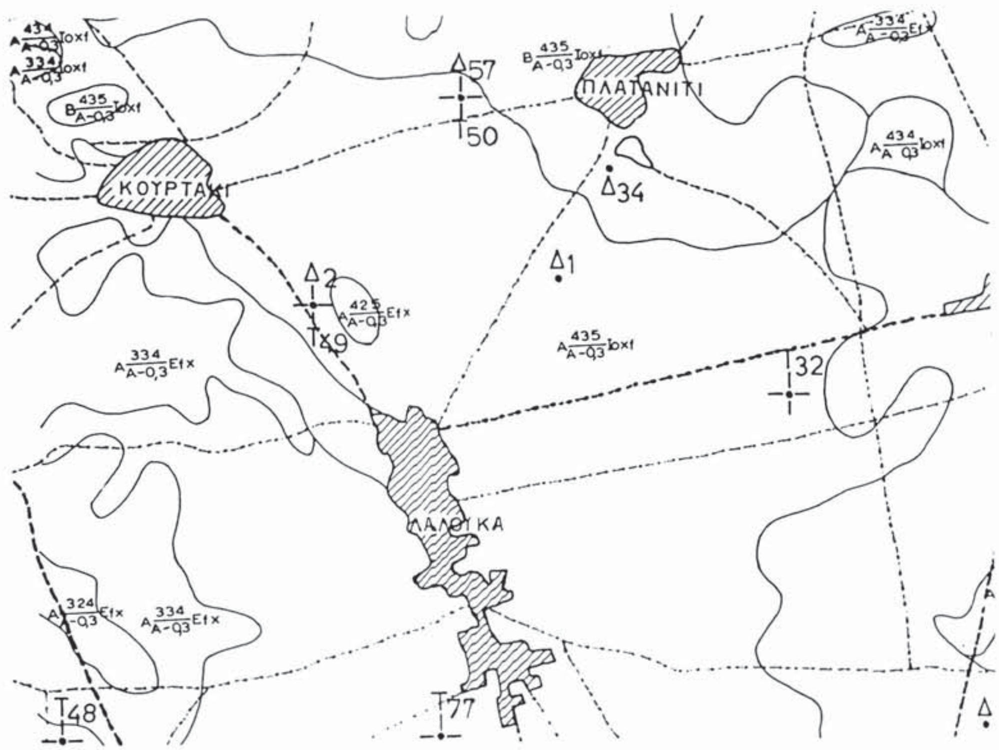

Figure 5(b) Manually produced detailed soil map for this area

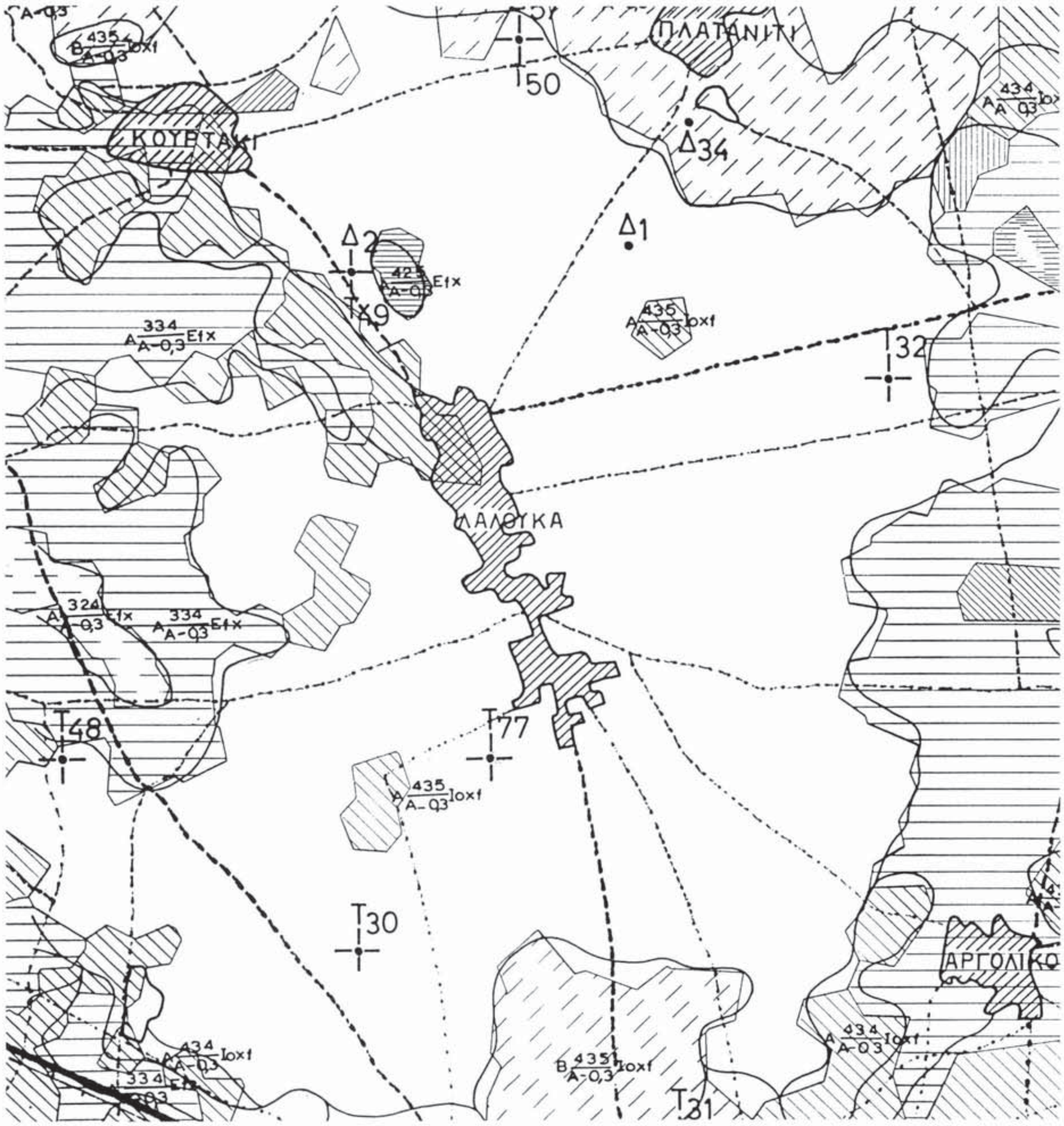

Figure 5(c) Computer generated soil polygons superimposed on manually generated detailed soil map