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Computer-based self-organized tectonic zoning revisited: Scientific criterion for determining the optimum number of zones

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ABSTRACT

As multivariate numerical classification become increasingly available to Earth Scientists, there is a corresponding need to introduce a scientific criterion or stopping rule to determine the optimum number of classifications. The increasing interest in comparative, experimental numerical zoning makes such a criterion highly desirable. In this research multivariate data comprising new and updated geological and geophysical characteristics of Iran have been used to construct Automatic Integrated Self-Organized Optimum Zoning (AISOOZ) maps. The Wilk's Lambda Criterion and the relative discrepancy of Wilk's Lambda have been applied for the first time as stopping rules to measure the relative usefulness of zoning maps. The application of these criteria has eventually led to an optimum map with 11 zones.

Our AISOOZ map reveals some remarkable features that cannot be observed on conventional tectonic maps of Iran. For example: contrary to the conventional maps, the AISOOZ map reveals the much disputed extent and rigidity of the microplate in the central and eastern parts of Iran and makes a clear distinction between the Makran ranges and the eastern Iran mountains. The AISOOZ method is a new approach to zoning, organized in a hierarchy of increasing complexity, and developed from reductionist approach. Based on this logic, the AISOOZ method casts an interesting light on the connection between the zoning hierarchy and the geodynamic evolution of the study area. It also helps to estimate the likelihood of earthquake occurrence for each zone. The AISOOZ map not only can be re-assessed quite often, but also provides us with a means for on-line information availability. The information can be tailored to the user's specific needs and down-loaded to the user's computer. Furthermore, the general approach presented in this paper could readily be adapted to pattern recognition and zoning maps of any space, regardless of context or scale.

1. Introduction

A major task in the Earth Sciences is to map any desired surface or subsurface part of the Earth characterized by similar geological history and development (Aghanabati, 1986, 2004; Alavi, 1991, 1994; Berberian, 1976, 1979, 1983; Berberian and King, 1981; Berberian and Yeats, 1999; Davoudzadeh et al., 1986; Davoudzadeh and Weber-Diefenbach, 1987; Eftekharnezhad, 1980; McCall, 1996; Nowroozi, 1971, 1976, 1979; Stöcklin, 1968; Stöcklin and Nabavi, 1973) (Fig. 1).

Typically, the attribute measurements gathered are not only correlated with each other, but each attribute is also influenced by the other attributes. Thus, in many instances the attributes are interwoven in such a way that when analyzed individually they yield little information about the region under investigation. In the past, geologists have primarily dealt with conventional maps on the basis of their appearance. However the development of more sophisticated technology to collect numerical data has outpaced geologists' ability to use it to full potential (Zamani and Hashemi, 2004; Zamani and Khalili, 2006, hereafter referred to as I and II respectively). Today, it is common to have massive numbers of observations which contain far more information about the Earth than can be modeled by conventional methods of geologic mapping. Such massive amounts of data require both statistical reduction and the ability to compute theoretical solutions in Earth models with many parameters. Since the publication of the first computer-based self-organized tectonic zoning (Fig. 2) (I; II) there was a need to come up with some scientific criteria for objective selection of the final or optimum number of zones to be recognized (also known as the stopping rule).

In this paper, which is an extension of I and II, many new and updated geological and geophysical characteristics of Iran have been used to construct computer-based self-organized tectonic zoning maps. For this purpose, Ward's method, which is most intuitive and computationally efficient, was chosen (Duda et al., 2001; Ward, 1963, I; II). This agglomerative (bottom-up) hierarchical clustering procedure results in tectonic zones of approximately equal size and avoids problems with "chaining" found in other agglomerative methods (I; II). Perhaps the most

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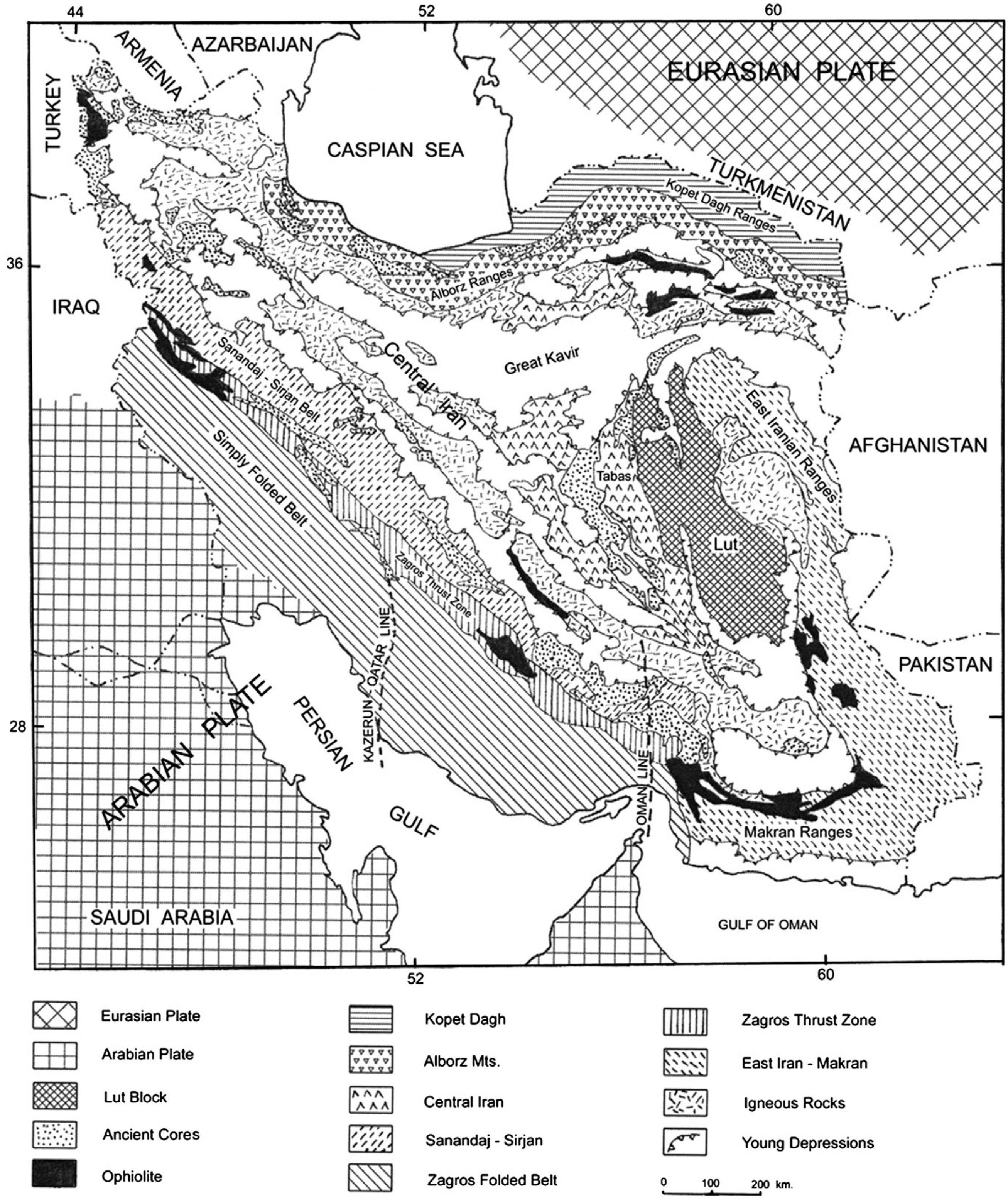

Fig. 1. Generalized tectonic map of Iran (modified from Stöcklin, 1968; Stöcklin and Nabavi, 1973 by Zamani and Hashemi, 2004).

perplexing issue in computer-based self-organized tectonic zoning using statistical methods is the objective selection of the final number of tectonic zones. In order to alleviate this deficiency, a stopping rule algorithm has been used for determining the final number of zones. To illustrate, Computer-Based Self-Organized Tectonic Zoning maps of Iran have been produced utilizing a large amount of new and updated geological and geophysical characteristics of Iran (I, II). Finally, by assessing the statistical significance of differences between tectonic zones the best, in the sense of most generally useful zoning, was identified.

2. Method of analysis

Cluster analysis is the generic name for a variety of statistical methods that search for patterns in a set of objects by grouping them