In this chapter uncertainty calculations, carried out by us will be discussed. We tried to cover different fields of geological investigations, both pure scientific and practical ones. Similar calculations, performed by other authors will also be presented in Sects. 5.5–5.7.

Simple geostatistical applications are not presented, as they have been discussed in numerous papers. A further reason for not discussing them is the fact that they are based on crisp input data, thus they cannot evaluate the entire uncertainty of a geological system (see Sect. 3.2).

Geological problems are generally imperfectly and vaguely defined. For this reason many geological objects do not fit well into the traditional classifications of rocks and rock properties. Paleontologic classifications have similar difficulties. In our opinion, the strict rules of the classical logic are inadequate to describe the real world of geology. The aim of this chapter is to show that the uncertainty oriented new mathematical methods are capable to model natural reality with both its uncertainties and transitions. The membership functions are particularly suitable to represent and to handle these two fundamental problems.

5.1 Estimation of Resources of Solid Mineral Deposits

In the following section only the resource estimation of solid mineral deposits will be discussed, the oil and gas fields being beyond our present experience. We mention only that a growing number of articles appeared in the last decade discussing the uncertainty of oil and gas resource estimations, see e.g. [48, 130]. We are convinced that uncertainty oriented mathematical methods can be successfully applied to the resource estimation of oil and gas deposits as well.
5.1.1 Basic Concepts of Resource Estimation

The estimation of resources and reserves is of paramount importance for mineral exploration and mining investments, for their financial investors and/or shareholders. The estimation results are used also by governments and international organisations, such as EU, OECD, World Energy Council etc., for national and global inventories of the raw materials. A great number of articles and several textbooks have been published on this subject, we cite here only the most important ones: [2, 46, 81, 82, 92, 122, 147, 151, 170, 171, 172]. Several methodologies have been suggested with the aim to produce reliable resource and reserve estimations. To eliminate the confusion arising from the different recommendations, the UN Economic and Social Council elaborated general recommendations for a unified classification of resources and reserves and published definitions of the estimation process [182]. This has been followed by a guideline for the practical application of the above mentioned general recommendations [183].

These two documents represented an important step ahead, however several questions remained unsolved, e.g. the quantification of the uncertainties of the estimation results, or the reliable calculation of the financial and technical risks related to the investments. We agree with Henley [96], that "there is no way to be confident that one company’s measured resource is comparable with another’s". In our opinion, everything possible has been done to produce the best results – within the framework of the traditional mathematical methods. But because of the theoretical limitations, discussed in Sect. 3.2, no satisfactory solution of the problems could be obtained. This is why we decided to apply the fuzzy set theory to resource and reserve estimations of solid mineral deposits. We intend to extend these calculations in the near future to oil and gas deposits as well. Bárdossy, R. Szabó and Varga [20, 21] carried out a number of test calculations on selected bauxite deposits of Hungary. These results are outlined in the following.

The terms mineral resource and mineral reserve are used by us according to the above mentioned UN recommendations [182]: "Mineral resource is defined as naturally occurring concentrations of mineral raw material of economic interest and with specified geological certainty". "Mineral reserve is the economically mineable part of the total mineral resource as demonstrated by a Feasibility Assessment”. Our attention is focused on the mineral resources, as the estimation of mineral reserves requires a number of additional financial and economical calculations, extending beyond the scope of geological investigations [96].

As a matter of principle, resource estimations are not limited to the calculation of overall tonnage and grade of the deposit, but they include evaluations of the spatial position, internal continuity and compositional variability of the given ore or mineral commodity. The entire estimation procedure is considered by us as a double geological and mathematical modeling process. The mathematical calculations are based on real numbers as input data. In tradi-