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STRUCTURAL GEOLOGY AND TECTONICS

A.S.Yo'ldoshaliyev
student of Fergana polytechnic institute, group E6-22 GKK, department of geodesy cartography and cadastre.
yoldoshaliyevazizbek4090@gmail.com

O.M.Mamalatipov
Tashkent named after Muhammad al-Khorazmi University of Information Technology Academic lyceum under the Fergana branch
teacher of mathematics.
mamalatipovodiljon5@gmail.com.

Abstract: *Structural geology and tectonics are fundamental disciplines within the field of geology, providing vital insights into the deformation and displacement processes that shape the Earth's crust. This abstract explores the fundamental principles and methodologies employed in studying the structures and tectonic processes that occur within the Earth's lithosphere. It discusses the classification and characteristics of geological structures, including folds, faults, and fractures, and emphasizes their significance in deciphering the tectonic history of a region*.

Key words: *faults, folds, plate boundaries, deformation, strain, stress, thrust faults, folded mountains, shear zones, tectonic plates, convergent boundary, orogeny, rift zones.*

INTRODUCTION

Structural geology and tectonics form the cornerstone of understanding the dynamic processes occurring within the Earth's crust. By examining the deformation and displacement of rock units, these disciplines provide crucial insights into the formation of geological structures and the tectonic forces driving them. This introduction sets the stage for exploring the fundamental principles, methodologies, and

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significance of structural geology and tectonics in deciphering the complexities of the Earth's lithosphere.

Structural geology primarily deals with the study of rock deformation, encompassing the analysis of folds, faults, fractures, and other geological structures. Through detailed examination of these structures, geologists unravel the tectonic history of a region, discerning the mechanisms behind crustal movements and the associated geological events. Tectonics, on the other hand, delves into the broader processes of deformation, including the formation of mountain ranges, the opening and closing of ocean basins, and the effects of plate tectonics. Together, these disciplines shed light on the dynamic nature of the Earth's crust and its evolution over geological time scales. The intertwined nature of structural geology and tectonics with other geological processes, such as sedimentation, metamorphism, and volcanism, underscores their integral role in understanding the Earth's history and its ongoing changes. Moreover, the practical implications of these disciplines extend to the exploration for natural resources, assessment of geological hazards, and the development of geological models for engineering and environmental purposes.This introduction lays the foundation for deeper exploration into the methodologies, advancements, and interdisciplinary connections of structural geology and tectonics, ultimately highlighting their profound influence on our understanding of Earth's dynamic processes and the development of sustainable geological practices.

Structural geology typically pertains to the observation, description and interpretation of structures that can be mapped in the field. How do we recognize deformation or strain in a rock? “Strained” means that something primary or preexisting has been geometrically modified, be it cross stratification, pebble shape, a primary magmatic texture or a preexisting deformation structure. Hence strain can be defined as a change in length or shape, and recognizing strain and deformation structures actually requires solid knowledge of undeformed rocks and their primary structures.

Being able to recognize tectonic deformation depends on our knowledge of primary structures.

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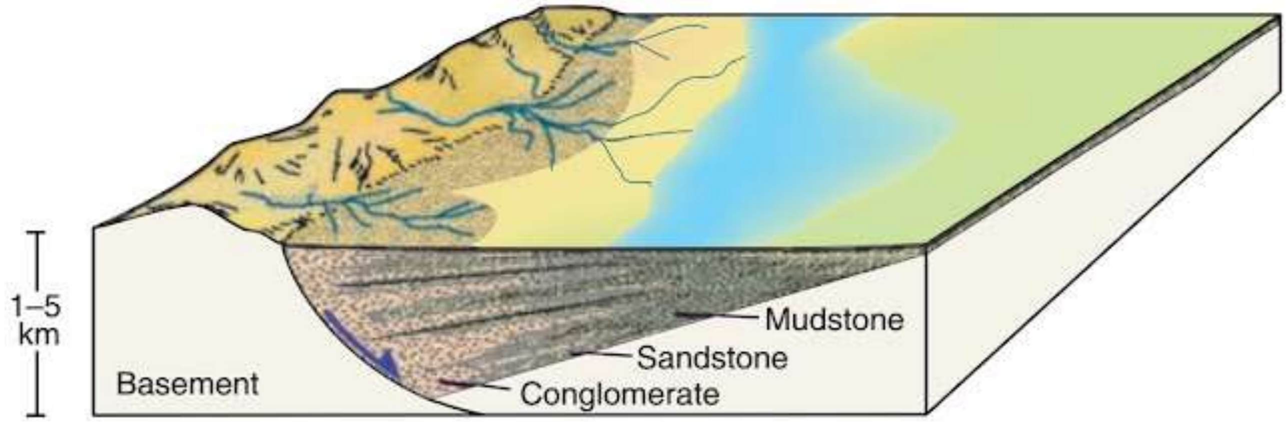

Fig. 1.

Illustration of the close relationship between sedimentary facies, layer thickness variations and syndepositional faulting (growth fault) along the margin of a sedimentary basin.[2]

Structural data sets

Planet Earth represents an incredibly complex physical system, and the structures that result from natural deformation reflect this fact through their multitude of expressions and histories. There is thus a need to simplify and identify the one or few most important factors that describe or lead to the recognition of deformation structures that can be seen or mapped in naturally deformed rocks. **Field observations** of deformed rocks and their structures represent the most direct and important source of information on how rocks deform, and objective observations and careful descriptions of naturally deformed rocks are the key to understanding natural deformation. Indirect observations of geologic structures by means of various **remote sensing methods**, including satellite data and seismic surveying, are becoming increasingly important in our mapping and description of structures and tectonic deformation. **Experiments** performed in the laboratory give us valuable knowledge of how various physical conditions, including stress field, boundary condition, temperature or the physical properties of the deforming material, relate to deformation. **Numerical models**, where rock deformation is simulated on a computer,

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are also useful as they allow us to control the various parameters and properties that influence deformation.

Experiments and numerical models not only help us understand how external and internal physical conditions control or predict the deformation structures that form, but also give information on how deformation structures evolve, i.e. they provide insights into the deformation history. In contrast, naturally deformed rocks represent end-results of natural deformation histories, and the history may be difficult to read out of the rocks themselves. Numerical and experimental models allow one to control rock properties and boundary conditions and explore their effect on deformation and deformation history. Nevertheless, any deformed rock contains some information about the history of deformation. The challenge is to know what to look for and to interpret this information. Numerical and experimental work aids in completing this task, together with objective and accurate field observations.[1]

Structural geology and tectonics are fundamental disciplines within the field of geology, focusing on the deformation and structural evolution of the Earth's crust. By studying the processes that shape rocks and the Earth's lithosphere, researchers gain insight into the dynamic forces that have shaped the Earth's surface over geological time scales. This discussion aims to highlight the significance of structural geology and tectonics in unraveling the Earth's tectonic history and its implications for various geoscience applications.

a. Deformational Features and Mechanisms:

Structural geology encompasses the analysis of various deformational features, including folds, faults, foliations, and lineations. Understanding the mechanisms responsible for their formation provides crucial insights into the kinematics and dynamics of crustal deformation. By characterizing the geometry and orientation of these features, structural geologists infer the stress and strain regimes that have acted upon the rocks, thereby unraveling the tectonic history of a region.

b. Tectonic Settings and Plate Tectonics:

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Tectonics encompasses the study of the large-scale processes governing the deformation of the Earth's lithosphere. Plate tectonics theory provides a unifying framework for understanding the distribution of earthquakes, volcanoes, and mountain ranges. By examining the geological structures and deformational patterns, researchers can infer the tectonic setting in which the rocks were deformed, providing critical evidence to support plate tectonics theory and refine our understanding of global tectonic processes.

c. Resource Exploration and Geohazards Assessment:

The insights derived from structural geology and tectonics play a vital role in resource exploration and geohazards assessment. Understanding the structural architecture of subsurface rock formations aids in the exploration and production of hydrocarbons, minerals, and groundwater resources. Moreover, the identification and characterization of geological structures contribute to assessing seismic hazards, landslides, and other geological risks, thereby informing land-use planning and infrastructure development.[3]

d. Crustal Evolution and Tectonic History:

Structural geology and tectonics provide a window into the past, allowing geoscientists to reconstruct the tectonic history and evolutionary processes that have shaped the Earth's lithosphere. By integrating structural data with geochronological and geochemical information, researchers unravel the timing and nature of tectonic events, leading to a deeper comprehension of mountain building, continental rifting, and other major tectonic phenomena.

e. Engineering and Geotechnical Applications:

The principles of structural geology and tectonics are integral to the field of engineering geology and geotechnical engineering. Assessing the orientation and stability of rock masses, understanding the potential for faulting or fracturing, and interpreting the impact of tectonic activity on infrastructure are essential for planning and constructing civil projects in tectonically active regions.

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Result

The field of Structural Geology and Tectonics focuses on understanding the deformation of the Earth's crust and the processes that drive it. Through geological mapping, analysis of rock structures, and studying tectonic activity, researchers seek to unravel the complex history of the Earth's movement and deformation. This knowledge is crucial for understanding seismic hazards, resource exploration, and the evolution of landscapes. Additionally, the field plays a key role in the exploration and development of natural resources such as oil, gas, and minerals. Overall, the study of structural geology and tectonics provides valuable insights into the dynamic processes that have shaped our planet over millions of years.

Seismic data

In the mapping of subsurface structures, seismic data are invaluable and since the 1960s have revolutionized our understanding of fault and fold geometry. Some seismic data are collected for purely academic purposes, but the vast majority of seismic data acquisition is motivated by exploration for petroleum and gas. Most seismic data are thus from rift basins and continental margins.

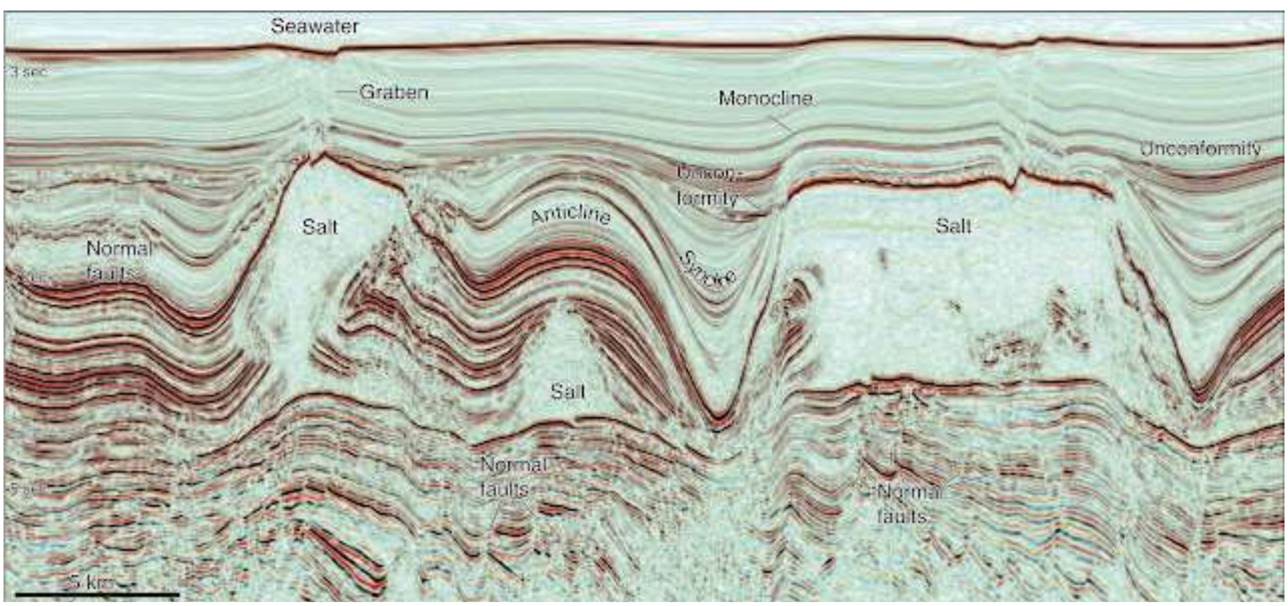

Fig 2.

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Seismic 2-D line from the Santos Basin offshore Brazil, illustrating how important structural aspects of the subsurface geology can be imaged by means of seismic exploration. Note that the vertical scale is in seconds.

Acquisition of seismic data is, by its nature, a special type of remote sensing (acoustic), although always treated separately in the geo-community. Marine seismic reflection data (Figure 6) are collected by boat, where a sound source (air gun) generates sound waves that penetrate the crustal layers under the sea bottom. Microphones can also be put on the sea floor. This method is more cumbersome, but enables both seismic S- and P-waves to be recorded (S-waves do not travel through water). Seismic data can also be collected onshore, putting the sound source and microphones (geophones) on the ground. The onshore sound source would usually be an explosive device or a vibrating truck, but even a sledgehammer or specially designed gun can be used for very shallow and local targets. [5]

The sound waves are reflected from layer boundaries where there is an increase in acoustic impedance, i.e. where there is an abrupt change in density and/or the velocity with which sound waves travel in the rock. A long line of microphones, onshore called geophones and offshore referred to as hydrophones, record the reflected sound signals and the time they appear at the surface. These data are collected in digital form and processed by computers to generate a seismic image of the underground.

Conculision

In my view, the study of structural geology and tectonics is essential for understanding the dynamic processes that shape the Earth's crust. This field of study provides valuable insights into the deformation of rocks, faulting, folding, and the formation of geological structures. By studying the tectonic forces at work, researchers can gain a better understanding of seismic activity, mountain building, and the distribution of natural resources. Furthermore, the principles of structural geology and tectonics are crucial in various industries, such as oil and gas exploration, mining, and civil engineering. The knowledge gained from this discipline is invaluable for

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predicting geological hazards and contributing to the sustainable development of our planet. As such, ongoing research and education in structural geology and tectonics are paramount for advancing our understanding of the Earth's dynamic processes and their implications for society.

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