2.7 The Impact of High Pressures and Temperatures on Fluid Density in a Porous Space Within Rocks and Rock Layers .................................................. 118
2.8 Density of Fluids in the Early Earth Atmosphere .................... 137
References ............................................................................. 142

3 Methods of Thermal Field Measurements .................................. 151
3.1 Different Methods of Thermal Field Measurements ................. 151
3.2 The Use of Thermistors and Fiber Optic Temperature Sensors .... 151
3.2.1 Thermistors .................................................................. 151
3.2.2 Fiber Optic Temperature Sensors .................................. 152
3.3 Measurements in Wells ....................................................... 153
3.4 Sea Measurements ............................................................. 154
3.5 Space Infrared Measurements ............................................ 155
3.6 Near-Surface Thermal Measurements .................................. 156
3.7 Measurements in Mines and Tunnels ................................. 158
References ............................................................................. 158

4 Temperature Anomalies Associated with Some Natural Phenomena .......................................................... 161
4.1 Thermal Waters, Hot Springs, Geysers and Fumaroles ............ 162
4.1.1 Key Definitions of Hydrogeology and Related Characteristics .............................................. 163
4.1.2 Thermal Waters .............................................................. 166
4.1.3 Hot Springs, Geysers, Fumaroles ..................................... 167
4.1.4 Oceanic Vents ................................................................ 182
4.2 Volcanic Eruptions ............................................................. 185
4.3 Mud Volcanoes .................................................................. 201
4.4 Formation of Overpressures and Ultrahigh Pressures in the Earth’s Strata ...................................................... 211
References ............................................................................. 224

5 The Thermal Regime of Permafrost Regions ............................... 239
5.1 The Temperature of Frozen Rocks ....................................... 239
5.2 Changes in the Mechanical and Thermal Properties of Formations at Thawing ...................................................... 241
5.3 Thickness and Dynamics of the Permafrost ......................... 249
5.4 Results of Long Term Temperature Surveys ....................... 252
5.5 Climate Change and the Temperature Regime of Permafrost .............................................................. 255
5.5.1 Forecasting Climate Change and the Permafrost Thickness for Central Yakutia ....................... 255
6 Investigating Deep Lithospheric Structures
6.1 The Formation and Evolution of the Magma-Ocean
6.2 The Early Earth’s Atmosphere and the Cooling of the Earth
6.3 The Thermal Regime During Early Lithosphere Formation
6.4 Markers of Thermal Conditions Within the Lithosphere During Its Evolution
6.5 Dynamic Interactions of the Asthenosphere and the Lithosphere
6.6 Reflecting the Earth’s Crust Structure in the Thermal Field
6.7 Computing the Curie Discontinuity Depth
6.8 Role of the Thermal Regime in Fold Formation in Sedimentary Strata
6.9 The Thermodynamic Regime and Its Influence on Tectonic Processes
References

7 Interpretation of Thermal Measurements
7.1 Development of a Geothermal Model
7.2 Methods of Geothermal Regime Analysis
7.3 Calculation of Horizontal and Vertical Gradients
7.4 Heat Absorption in the Earth’s Strata
7.4.1 Formal Theory of Heat Absorption in Layers of Crust
7.5 Quantitative Interpretation of Temperature Anomalies
7.5.1 Typical Features of Gravitational, Magnetic and Temperature Anomalies
7.5.2 Brief Description of the Methods Employed for Quantitative Interpretation of Magnetic Anomalies in Complex Conditions
7.6 Investigation of Strongly Nonlinear Thermal Sources
7.6.1 Nonlinear Effects in Geophysics and Thermal Processes in the Earth
7.6.2 Problem Definition and Discussion
7.6.3 Transition Waves and Their Definitions
7.6.4 Some Applications of this Approach
7.7 Thermal Anomalies as Precursors of Dangerous Geodynamic Events
7.7.1 Mathematical Models of Strongly Nonlinear Geophysical Phenomena
7.7.2 Thermal Precursors of Earthquakes
References
8 Temperature Investigations in the Petroleum Industry

8.1 Wellbore and Formation Temperatures During Drilling

8.1.1 Heat Exchange in the Wellbore-Formation System
8.1.2 Downhole Circulating Mud Temperature
8.1.3 Drilling Fluid Densities at High Temperatures and Pressures
8.1.4 Hydrostatic Mud Pressure
8.1.5 Drilling Through Hydrates

8.2 Wellbore and Formation Temperatures During Shut-In

8.2.1 Calculating the Downhole Shut-In Temperatures
8.2.2 Prediction of Formation Temperatures
8.2.3 Temperature Distribution in Formations
8.2.4 Calculating the Formation Temperature from BHT Logs

8.3 Permafrost Regions

8.3.1 Low and High Temperature Permafrost
8.3.2 Temperature Distribution and the Radius of Thermal Influence
8.3.3 Radius of Thawing Around a Production or Injection Well
8.3.4 Time of Complete Freezback
8.3.5 Prediction of Formation Temperatures: Field Cases

8.4 Cementing of Casing: Cement Heat Generation

8.4.1 Strength and Thickening Time of Cement
8.4.2 Rate of Heat Generation Versus Time
8.4.3 Hydration Test Data and Field Data
8.4.4 Temperature Increase at Cement Hydration
8.4.5 Size of the Annulus
8.4.6 Thermal Properties and Temperature of Formations
8.4.7 Radius of Thermal Influence at Cementing

References

9 Temperature Analyses in Hydrology

9.1 The Horner Method and Its Modifications (Permeability and Skin Factor)

9.1.1 Effect of Vertical and Horizontal Water Movements on Temperature Profiles
9.1.2 Application of the Horner Method

9.2 Temperature Profiles in Water Injection and Production Wells

9.2.1 Overall Coefficient of Heat Loss
9.2.2 Example of a Calculation

9.3 Monitoring Water Reserves

References
10 Near-Surface Temperature Measurements ........................................... 619
  10.1 General Introduction ............................................................. 619
  10.2 Calculation of Temporary Variations ..................................... 622
  10.3 Calculation of Terrain Relief Influence .................................. 623
  10.4 Quantitative Interpretation .................................................... 624
  10.5 Prospecting of Hard Economic Minerals .................................... 625
    10.5.1 Surface Measurements .................................................. 625
    10.5.2 Prospecting of Hard Economic Minerals in Mines ............... 628
  10.6 Prospecting for Oil and Gas Deposits ..................................... 634
  10.7 Delineation of Archaeological Features .................................. 638
    10.7.1 Some Precursors of NSTM .............................................. 638
    10.7.2 Examples of Quantitative Analysis of Temperature
        Anomalies Observed Over Archeological Features ............... 640
    10.7.3 Temperature Field Modeling by Mathematical Analogy
        to the Magnetic Field .................................................. 641
  10.8 Mapping Underground Caves .................................................. 643
  10.9 Mapping Karst Terranes ....................................................... 643
  10.10 Other Applications ............................................................. 645
    10.10.1 Environmental and Engineering Investigations
        in Deep Tunnels ................................................................ 645
    10.10.2 Delineation of a Flowing Landslide .............................. 646
    10.10.3 Submarine Spring Mapping ............................................ 647
    10.10.4 Monitoring Metallurgical Slag ...................................... 649
  10.11 Future Trends in Near-Surface Thermics .................................. 650
References ...................................................................................... 651

11 Paleoclimate and Present Climate Warming Trends .......................... 655
  11.1 Glaciations as a Strongly Nonlinear Phenomenon ....................... 657
  11.2 Studying Recent Paleoclimatic Changes ................................... 659
    11.2.1 Ground Surface Temperature Histories ............................ 659
    11.2.2 Introduction to the Problem ......................................... 661
    11.2.3 Climate Reconstruction Methods: Some Typical
        Disturbances and Restrictions ......................................... 661
    11.2.4 Mathematical Models and Assumptions ............................ 663
    11.2.5 Example of Calculations ............................................. 666
    11.2.6 Inversion Results ....................................................... 668
    11.2.7 Calculation of Warming Rates ..................................... 670
  11.3 Sea Level Changes and Paleoclimate ....................................... 673
    11.3.1 “Heat Island Effect” and Its Influence
        on Subsurface Temperature ............................................ 674
    11.3.2 Working Equations ..................................................... 674
    11.3.3 Example of Calculations ............................................. 677
  11.4 Long and Short Term Monitoring of Subsurface Temperatures
      in Observational Wells ...................................................... 679
11.4.1 Basic Issues ................................. 679
11.4.2 A Simple Method of Temperature and Gradient Evaluation ................ 679
11.4.3 Application of the $\gamma$-Function .......................... 681
11.4.4 Slider’s Method ................................ 683
11.4.5 Results of Computations .............................. 683
References ........................................... 690

12 Influence of Temperature Changes to Other Fields ..................... 695
12.1 Correlations Between Temperature and Other Physical Parameters ........ 695
12.1.1 Correlations Between Various Geothermal Parameters and Environments .... 695
12.1.2 Thermal and Density Properties .................................. 699
12.1.3 Temperature and Electric Properties .................................. 700
12.1.4 Temperature and Seismic Velocities .................................. 702
12.1.5 Temperature and Magnetic Properties ............................... 704
12.1.6 Temperature and Electromagnetic Properties ............................ 704
12.1.7 Temperature and Radon Anomalies .................................... 705
12.1.8 Temperature and Induced Polarization .................................. 706
12.1.9 Temperature and the Self-Potential Field ............................... 706
References ........................................... 707

13 Integration of Thermal Observations with Other Geophysical Methods ........ 709
13.1 Theoretical Preferences for Integration .................................. 709
13.2 Types of Integration Methodologies ...................................... 710
13.2.1 Conventional Integration ............................................. 711
13.2.2 Integration on the Basis of Information Theory ....................... 712
13.2.3 Multimodel Approach to Geophysical Data Analysis .................... 723
13.3 Case Histories ............................................. 723
13.3.1 Integrated Geophysical Investigations of Areas of the Saaty Super-Deep Borehole .... 723
13.3.2 Integrated Thermal-Gravity-VLF Investigations in Ore Geophysics .......... 725
13.3.3 Integrated Thermal-Gravity-Magnetic Investigations in Oil and Gas Geophysics ........ 728
13.3.4 Integrated Delineation of Ring Structures in Israel and the Easternmost Mediterranean ... 730
References ........................................... 730
Biographies of the Authors ........................................ 733

Appendix A: Computing Water Flow Geodynamics in Stratified Liquids. ....................... 735

Appendix B: Water Production Using the Air-Cooling Method .......... 739

Index ......................................................................... 745
Applied Geothermics
Eppelbaum, L.; Kutasov, I.; Pilchin, A.
2014, XVIII, 751 p. 204 illus., 21 illus. in color.,
Hardcover
ISBN: 978-3-642-34022-2