Notes on symposium "Geophysics and Ground Water: Methods, Applications", AGU Fall Meeting, 1981

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The Hydrology Section of the American Geophysical Union sponsored a one day symposuim on "Geophysics and Groundwater: Methods and Applications" as part of the AGU Fall meeting held in San Francisco, December 1981. The author gave a paper at the symposium and heard all of the other papers. As many of the reports were relevant to the issues of toxic and radioactive waste disposal, it is considered that a record of the symposium that is suitable for distribution to others in the EMR/AECL radwaste programme is useful. That is the purpose of this report.

The symposium was presided over by A.I. Johnson, of Woodward-Clyde Consultants, Denver, and it was divided into two separate but complementary parts. The morning session was devoted to the problems of surface geophysics and groundwater, while in the afternoon papers were devoted to techniques and results of borehole geophysics. Both sessions began with review papers. Several papers that were originally in the schedule were withdrawn.

Surface geophysics

1. Review paper "Surface geophysics and groundwater-state of the art", L.S.Collett, Geological Survey of Canada, Ottawa.

- electromagnetic and seismic methods have traditionally been used for delineating subsurface structures
- a water crisis is likely to develop in the next decade, and geophysics will be increasingly called upon to aid in the inventory of groundwater and to monitor its quality and movement underground
- use of microcomputers in the field has greatly speeded up data acquisition, analysis and interpretation
- high resolution seismic reflection methods and radar techniques are likely to be the methods that will undergo the most development and be of the most use in groundwater problems.

2. "Resistivity exploration for ground water", A.A.R. Zohdy, U.S.G.S., Denver, Colo.
   - several developments over the past fifteen years have occurred in the techniques of d.c. resistivity measurements; e.g. Schlumberger soundings can have electrode spacings of up to 10 km; sounding data need not be obtained along straight roads
   - uses in ground water research include mapping buried stream channels, study of saline water intrusion into coastal aquifers, mapping depth and thickness of volcanic aquifers (e.g. Snake River plain, Idaho), mapping depth of fresh-saline water interface in basins, mapping depth of water table, geothermal resource mapping
   - limitations include problems arising from cultural sources (e.g. fences, pipelines)

3. "An ellipsoid surface electrical resistivity model" D.T. Pederson, Univ. of Nebraska-Lincoln; O.L. Goodenkauf and R.E. Cady.
   - a model has been developed that can present data obtained from Wenner array soundings in a form that can be compared directly to borehole drillers' and resistance logs

4. "An improved method of computing apparent resistivity" W.G. Keck, Keck Consulting Services Inc, Williamston, Mich., G. Henry and R.C. Minning.
   - an improved mathematical modelling technique for computing apparent resistivity has been developed
   - method overcomes masking effect of near surface resistivity variations
   - potential application is detection of ground water contamination plumes. Studies of hypothetical cases seem to confirm this applicability.

5. "Electrical prospecting for contaminated ground water", D.J. Stierman, Univ. of California, Riverside.
   - a hazardous waste disposal site near Riverside has enabled monitoring of changes in electrical parameters by various sounding techniques
   - significant flow of toxic fluids has occurred parallel with a major joint system in the granitic bedrock

- dipole-dipole soundings produce pseudosections that correlate well with observations of conductivity changes in monitoring wells.

6. "High resolution seismic reflection methods and their application to hydrologic studies in Connecticut and Florida" F.P. Haeni, U.S.G.S.,Hartford, Conn.
   - uses techniques of shallow marine seismics in rivers and lakes, in water less than 3 m deep
   - have identified bedrock surface beneath 60m of stratified drift in Connecticut
   - continuity of shallow aquifers successfully observed in Florida

7. "Geophysical Reconnaissance of Lemmon Valley, Nevada", D.H. Shaefer and D.K. Maurer, U.S.G.S., Carson City.
   - gravity and electrical resistivity surveys were used in an attempt to determine depth to bedrock and depth to freshwater
   - maximum depth of poor-quality water, defined as having a resistivity less than 20 ohm m, varied considerably, from 12 - 150 m.

Borehole geophysics

The invited review paper was to have been given by W. Scott Keys of U.S.G.S., Denver. However, it was announced that Keys' supervisor had changed his mind and refused him permission to attend. The paper was given instead by W.J. Head, Woodward-Clyde Consultants, Houston.

8. Review paper: "Borehole geophysics and ground water: state of the art"
   - the paper provided a good review of the various logging methods
   - the historical development of logging, from simple, portable, analogue systems to microprocessor-controlled digital systems was discussed
   - analogue methods are not as good as digital ones

9. "Determining hydrogeologic properties of deep water formations using seismic, gravity and borehole techniques", W.J. Head.
   - described a multidisciplinary study of deep carbonate formations, using both surface and borehole techniques, with borehole data providing "underground truth"
   - patterns of water quality determined from log analysis can be used in conjunction with temperature data to estimate location of zones of ground water flow
   - most of estimated flow aligns with structural trends and basin features that are themselves indicated by Bouguer gravity trends. Gravity surveys can thus delineate ground water flow patterns.

10. "Shallow seismic reflections from a .22 rifle source", D.W. Steeples and R.W. Knapp, Kansas Geological Survey, Lawrence.
   - an off-the-shelf .22 calibre hunting rifle was fastened to the surface casing of boreholes and used as a seismic source when shot vertically into the hole
   - dominant frequencies well above 200 Hz were obtained
   - seismic reflections from depths as shallow as 20 m were observed
   - under favourable conditions reflections in depth range 10 - 100 m might be possible

11. "Borehole measurements in low permeability granitic rock at Stripa, Sweden", P.H. Nelson and R. Rachiele, LBL, California.
   - reported on results of a suite of borehole logs in small diameter boreholes in a quartz monzonite pluton
   - high U and Th in monzonite generated radon that became dissolved in water flowing down borehole
   - this flow detected by gamma-ray log: flow estimated as approximately 5×10^{-8} m s^{-1} (Author's note: the sensitivity is therefore at least as good as that of estimating flow rates from temperature anomalies. Such a flow rate would correspond to a temperature anomaly of approximately 1 mK in a typical Shield borehole)

- resistivity logs do not permit good estimates of porosity to be made, because of effects of electrochemical surface conduction in low porosity rock (Comment: this phenomenon has been generally ignored in the past - it might be a crucial factor in earthquake prediction)

12. "Density of basin-fill deposits calculated from borehole gravity data in four basins in central and southern Arizona", P. Tucci, U.S. G.S., Tuscon.
    - density values for basin-fill deposits were obtained from borehole gravity data
    - porosity calculated from borehole gravity data depends on grain density of basin fill
    - high density deposits have low hydraulic conductivity (Comment: this paper did not present anything that was not rather obvious)

13. "Gravity measurements applied to the investigation and prediction of earth fissures related to ground water withdrawal in Phoenix, Arizona", M.K. Larson and T.L. Péwé, Arizona State Univ., Tempe.
    - the presentation consisted mainly of aerial photographs of suburban Phoenix

14. "The detection of ground water flow by precise temperature measurements in boreholes", Drury, Jessop, Judge and Lewis
    - the work that this talk summarised has been discussed in various internal reports

15. "Relations between aquifer hydraulic and electrical properties", P.F. Reiter and W.E. Kelly, Univ. of Rhode Island, Kingston.
    - discussed relationship between observed electrical resistivity and porosity (Archie's law) and its extension to permeability and hence hydraulic conductivity
    - valid relationship between formation factor (ratio of bulk rock resistivity to fluid resistivity) and hydraulic conductivity only exists when transverse resistance of aquifer uniquely defined by sounding curve, as only this incorporates aquifer thickness

16. "A geophysical - geohydrological study of the Brée River valley, South Africa", R. Meyer, C.S.I.R., Pretoria
    - multidisciplinary study mainly Schlumberger soundings and borehole studies to determine extent and thickness of alluvial aquifer
    - empirical Archie's law-type relationship between permeability and resistivity was determined; this provided a basis for delineating most permeable areas of aquifer
    - showed the importance of multidisciplinary approach, using both surface and borehole methods

17. "Geophysical investigations as applied to hydrogeologic studies on the Hanford site, South-central Washington", B.A. Moore and S.R. Strait, Rockwell Hanford Operations, Richland
    - basaltic study area for radioactive waste disposal
    - gravity and magnetic surveys used to delineate basalt erosional surfaces
    - electrical methods delineated depth to basalts
    - aim was to develop map of basalt flow members in order to model ground water flow

    (Comment: the authors did not have a lot to say, nor were they concerned with borehole geophysics)

The abstracts of the papers are given in Eos, Transactions of the AGU, v2, pp 861-864, November 10, 1981. One interesting and recurring theme, particularly in the borehole geophysics session, was the lack of imagination and understanding that hydrogeologists seem to have when asked to consider the results of geophysical work. In general, the symposium was useful and most of the papers were good, well-presented and relevant. The fact that the room in which the symposium was held was overheated and underventilated serves as a commendation for those participants who stayed the course throughout the day.