

Section 4c: Self Potential Surveys

Natural Potentials in the Earth

Spontaneous or self potential (SP) refer to natural electrical potential differences that exist in the Earth.

SP first measured by Robert Fox in 1830 with copper-plate electrodes connected to a galvanometer. Located underground copper sulphide deposits in Cornwall, England.

- ❖ SP is a passive geophysical technique that measures ground potentials at the Earth's surface or in boreholes.
- ❖ SP has been used since 1920 as a secondary tool in base metal exploration to locate *massive ore bodies*.
- ❖ In contrast IP is used predominantly for *disseminated ore bodies*.
- ❖ Recently SP has been extended to groundwater and geothermal investigations.

Types of Self Potentials in the Earth

Origin of some self-potentials still unclear, but they comprise two components:

- ❖ Mineral potential: is constant and arises from electrochemical processes.
- ❖ Background potential: varies with time due to varied factors from heavy rainfall to alternating currents induced by thunderstorms. Two types are electrokinetic and electrochemical.

Examples of SP anomalies:

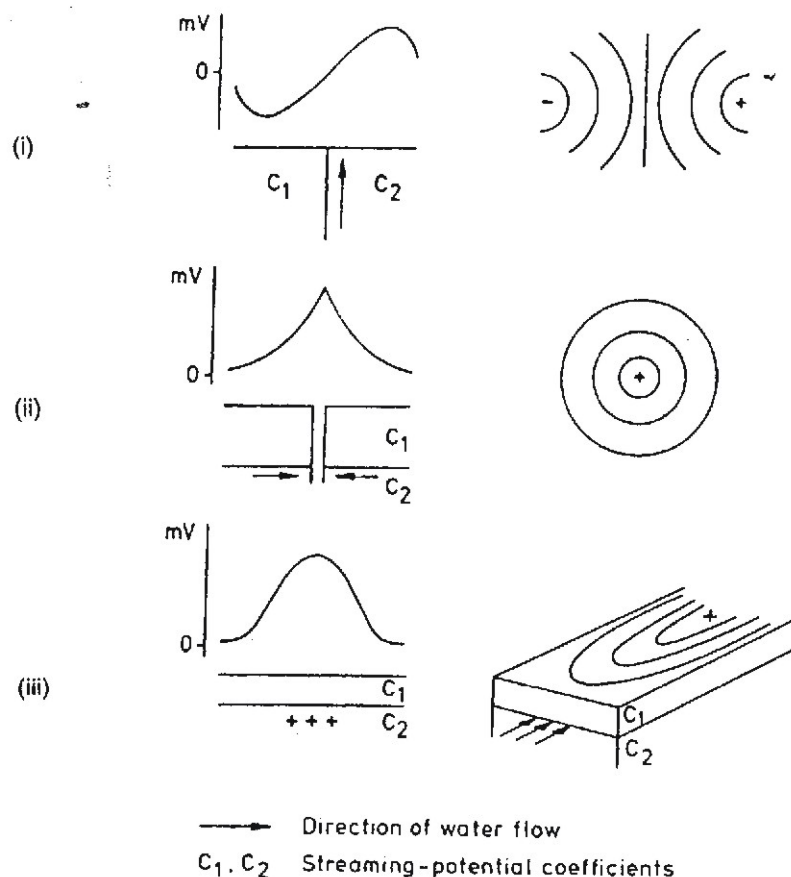
Source	SP Anomaly
<i>Mineral Potentials</i>	
Sulphide or graphite ore bodies, magnetite and other electronically conducting minerals, coal, manganese	Negative; 100-1000 mV
Quartz veins, pegmatites	Positive; 10-100 mV
<i>Background Potentials</i>	
Fluid streaming, geochemical reactions	Positive/Negative; < 100 mV
Bioelectric effects from plants, trees	Negative; < 300 mV
Groundwater movement	Positive/negative; 100-1000 mV
Topography	Negative; up to 2000 mV

Groundwater is the common factor in all processes that generate self potentials: flowing, as an electrolyte, as a solvent.

Electrokinetic (Streaming) Potentials

Electrokinetic potential E_k created when an electrolyte flows through a capillary or a porous medium.

- ❖ Flow of electric current related to hydraulic gradient and physical/electrical properties of electrolyte and pores
- ❖ Electrokinetic potentials thought to be due to fluid flow parallel to a geological boundary or the water table, at which the properties change abruptly:



- Flow along fault
- Groundwater pumping
- Flow along water table

Electrokinetic potentials tend to become more positive in the direction of fluid flow, which is opposite to the flow of negative charge.

Examples of Electrokinetic Potentials

Electrokinetic anomalies associated with the following:

Topography

Negative charge tends to flow uphill as water flows downhill.

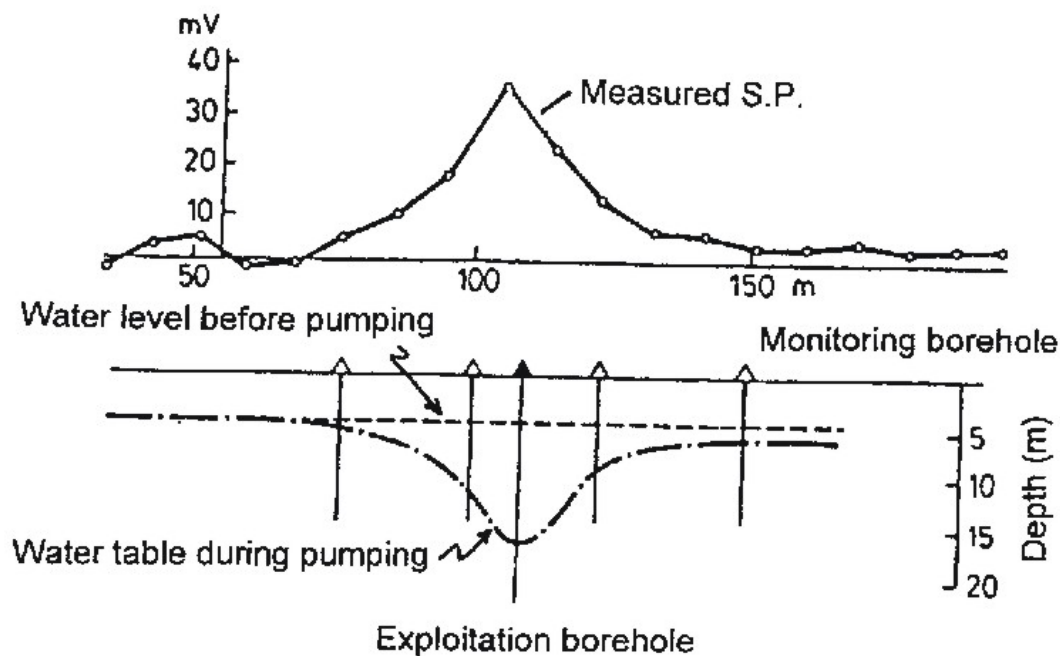
- ❖ Very large negative SP anomalies can be produced on topographic highs.
- ❖ Values of -2693 mV have been reported at the peak of Adak volcano in Alaska, -1842 mV on a mountain in Peru.
- ❖ Topographic effect requires correction where slope angles exceed 20° .

Heavy rainfall

Short-lived SP anomalies of the order of 5 mV can be produced as the water from heavy rainfall percolates through the soil.

Groundwater Pumping

SP potentials of ~ 10 s mV can be produced by pumping groundwater.



Electrochemical Potentials

Diffusion (liquid-junction) Potential

Diffusion potentials ~10s mV can arise from differences in mobilities of electrolytes with different concentrations in groundwater.

- ❖ Must be mechanism to maintain imbalances in the electrolytic concentrations otherwise diffusion of ions will remove any potential gradient.

Nernst (shale) Potential

Created by different ion concentrations at electrodes:

- ❖ When two identical electrodes are immersed in a homogeneous solution, there is no potential difference between them.
- ❖ If concentration of solution different at the two electrodes, then a potential difference will exist.

Electrochemical Potential

The *diffusion* and *Nernst* potentials can be combined to give a single *electrochemical* potential.

Example

For NaCl solution in which concentration differs by factor of 5, a potential of ± 50 mV is generated at 25°.

Electrochemical potentials increase with differences in solution concentration and temperature.

Mineral Potentials

Electrode Contact Potential

Potential difference between two dissimilar metal electrodes immersed in a homogeneous solution.

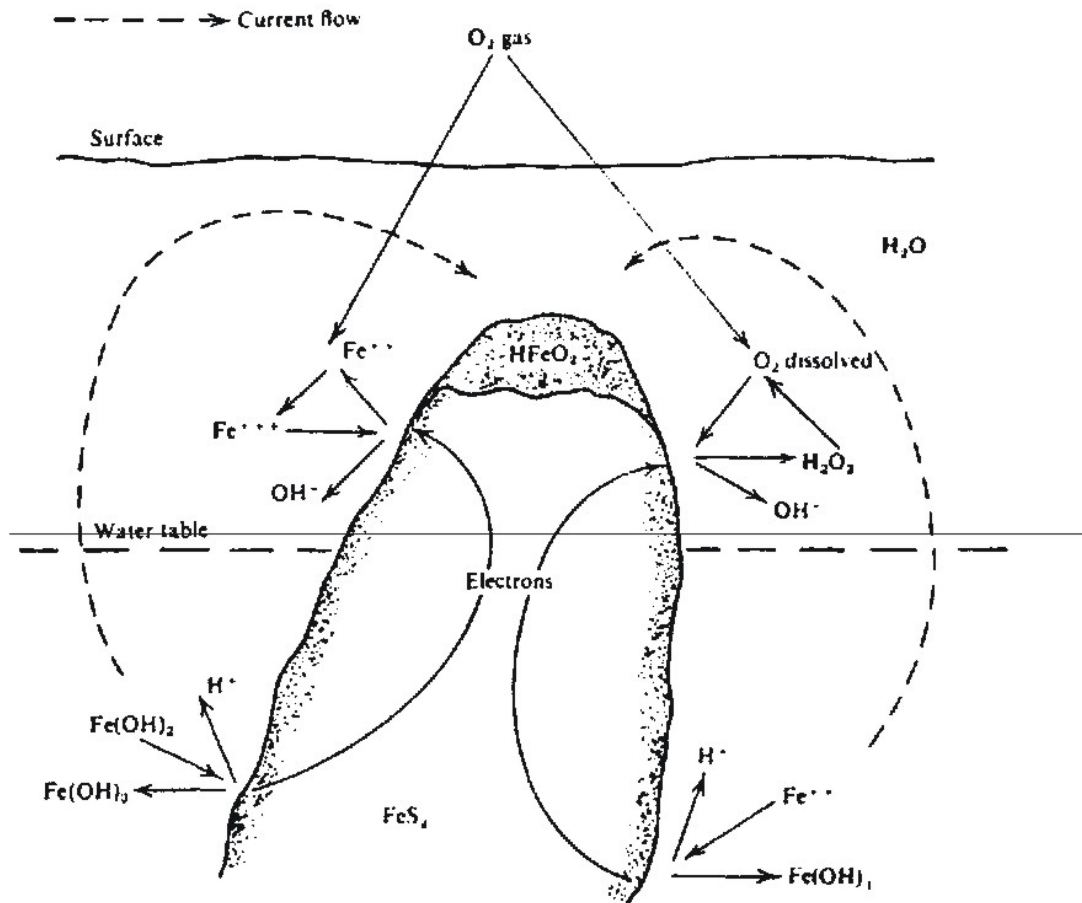
Mineral Potential

The mineral potential results from a combination of the contact electrode and electrochemical potentials, and is associated with some mineral deposits.

Large potentials observed over certain ore bodies containing good electronic conductors, such as pyrite or graphite, are too large to be explained by electrochemical effects alone (~100s to >1000 mV).

Mineral Potentials of Ore Bodies

Large mineral potentials occur where ore body straddles water table



May be due to oxidation/reduction reactions below/above water table

- ❖ **Above water table**, ions in surrounding electrolyte are chemically reduced; i.e. they gain electrons.
- ❖ **Below water table**, ions are oxidised; i.e. they lose electrons.
- ❖ Sulphide ore body allows electrons to move from below to above the water table by electronic conduction through the ore body.
- ❖ The flow of electrons leaves the upper part of the ore body with a net -ve charge, the lower part with a net +ve charge.

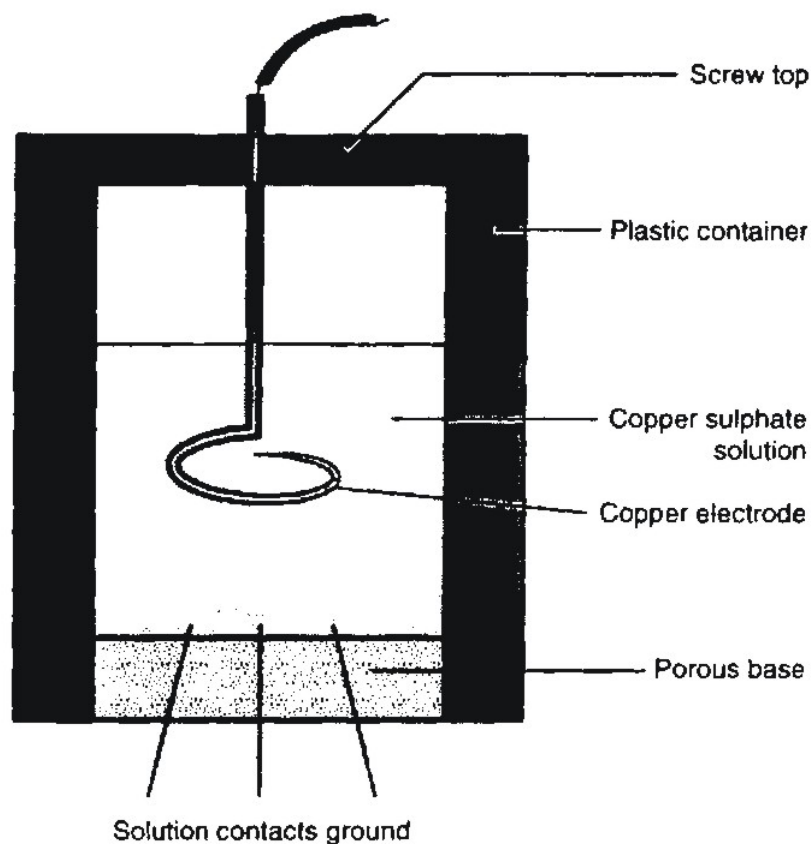
Still problems with this explanation, because SP anomalies are also observed over sphalerite, which is a poor conductor!

Porous-Pot Electrodes in SP Surveying

SP surveying is very simple.

Two non-polarising porous-pot electrodes are connected to a precision voltmeter capable of measuring to 1 mV resolution.

- ❖ Using as electrodes metal stakes driven into the ground (as in DC resistivity) would create spurious potentials at the electrode similar in size to those being measured.
- ❖ Non-polarising porous-pot electrodes, comprising a metal immersed in a saturated solution of its own salt that can percolate into the ground, are used, for example Cu in Cu SO₄, Zn in Zn SO₄ or Ag in AgCl.



SP Surveying

Two survey methods both carried out perpendicular to geological strike:

1) *Potential gradient.*

Two electrodes at a fixed separation of 5-10 m are leap-frogged, one over the other, along a survey profile.

- ❖ Measured potential difference is divided by the electrode separation to give a potential gradient in mV/m, and this value is assigned to the midpoint between the two electrodes.
- ❖ Care must be taken to keep track of the potential polarity, and errors can accumulate.

2) *Potential amplitude*

One electrode is kept fixed at a base station on unmineralised ground.

- ❖ Potential difference is measured between base and the second electrode, which is moved along the survey profile.
- ❖ The temperature of the two pots should be maintained similar to avoid creating an unwanted potential; 0.5 mV/oC for Cu/ Cu SO₄.

Self-potentials have an alternating component, at around 5-10 Hz, caused by atmospheric effects. Can be partly cancelled out by taking measurements at different times of day.

Electrical noise from measurements too close to streams or after heavy rain due to high streaming potentials.

Depths of investigation are around 60-100m depending on depth of ore body and the nature of the overburden.

Corrections to SP Data

Typically, two corrections applied to SP data:

1) *Regional trend*

- ❖ SP values measured over many square kilometres may have a regional trend due to telluric currents of >100 mV/km.
- ❖ To isolate any anomaly, regional trend must be removed in similar way to gravity data.

2) *Bioelectric effects*

- ❖ Bioelectric potentials, usually negative ~ 100 mV or so, can arise due to contrast between bare and vegetated ground.
- ❖ Estimated and removed in similar way to regional.

Interpretation of SP Data

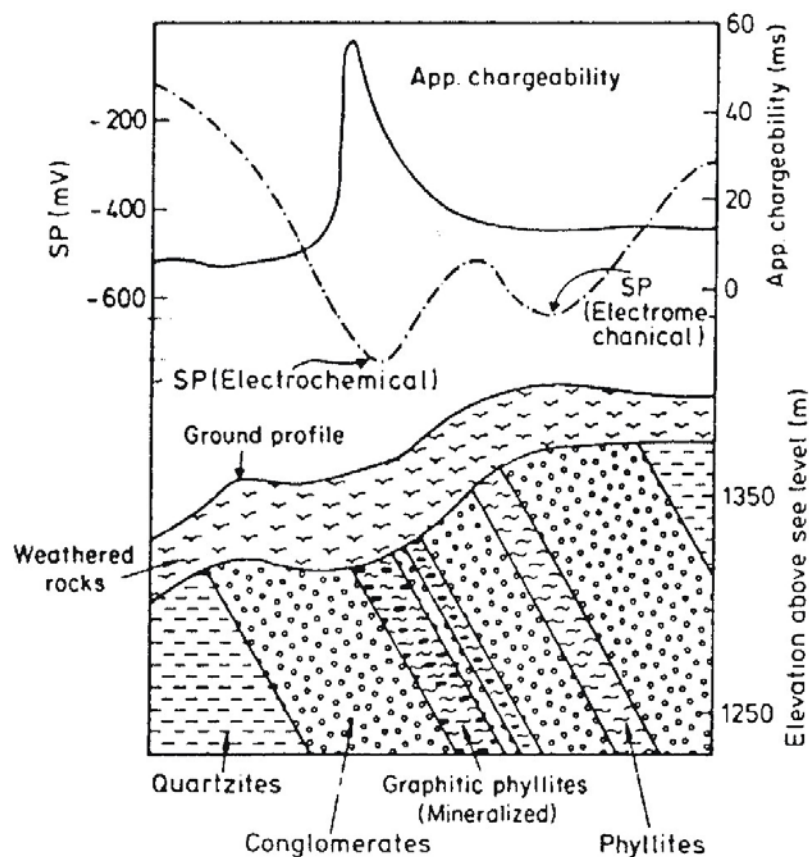
SP data is usually interpreted in a qualitative way.

Top of an ore body is assumed to lie beneath the position of minimum potential, but may be displaced downhill in areas of topography.

If the ore body is inclined, then the SP anomaly will become asymmetrical, with the steepest slope and +ve tail downdip.

Complications can arise when two or more features give rise to distinct SP anomalies that are superimposed.

Example



Two SP minima:

- ❖ one caused by electrochemical processes linked to mineralised graphitic phyllites,
- ❖ one caused by downward flowing water in permeable, disintegrated conglomerates.