



## SPQ Module 9 - Breathing at Altitude

For most people traveling 1130 kilometers on foot over a frozen ice cap with no support would be daunting enough without facing the prospect of being short of breath because of decreased oxygen availability. Unfortunately, there is less oxygen effectively available to people standing at the South Pole. Why is this?

Most of us take oxygen for granted. It is essential for life and it is there for us to breathe at will. However as you climb uphill from sea level the effective available oxygen in the air steadily decreases. The South Pole sits at 9,301 feet and the average elevation of Antarctica is 7,546 feet. This makes Antarctica the highest continent in the world and means there is less effectively available oxygen to breathe in Antarctica than on any other continent.

There is a scale that defines altitude as follows:

- High altitude: 8,000 to 12,000 feet
- Very high altitude: 12,000 to 18,000 feet
- Extreme altitude: 18,000 + feet

This places the South Pole, and most of the Antarctic Plateau at high altitude. At this level the effective available oxygen at the South Pole is reduced by over thirty percent compared to sea level.

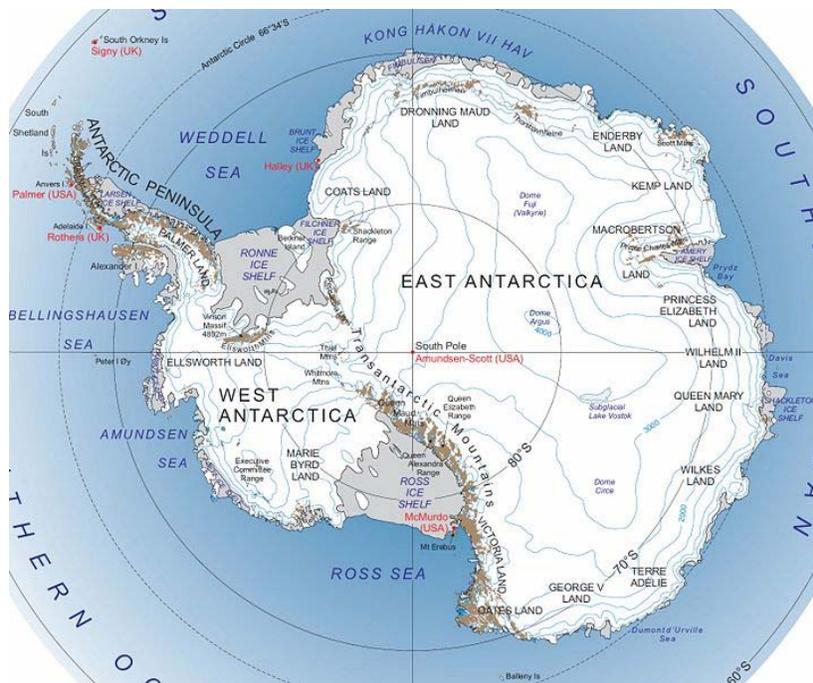


Figure 1: Map of Antarctica showing contour elevations. (Source NASA)

It has long been understood that the high elevation of Antarctica posed an additional obstacle to South Polar exploration. On the first expedition to penetrate deep onto the Antarctic Plateau, Ernest Shackleton and his compatriots were stricken with shortness of breath, nausea and headaches - symptoms consistent with mild altitude sickness. However the effects of high altitude do not affect all people equally. Roald Amundsen recounts in 'The South Pole' that during his climb from sea level to the Antarctic Plateau that,

“We were ascending rapidly, but, in spite of the sudden change in pressure, we did not yet experience any difficulty of breathing, headache, or other unpleasant results.”

In fact Amundsen and his team seemed to tolerate the high elevation of the Polar Plateau very well. This may have in part been due to the fact that they did not have to over-exert themselves given that their sledges were being pulled by dog-team.

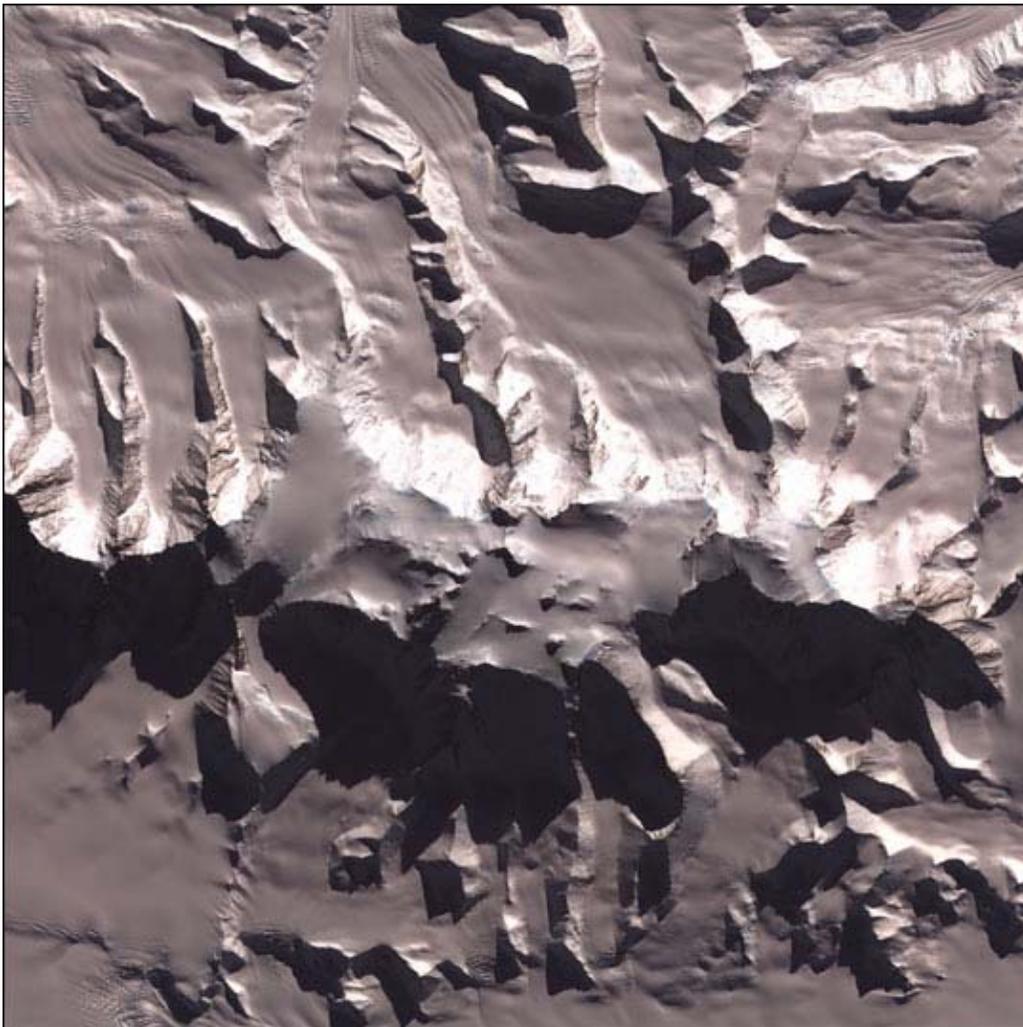
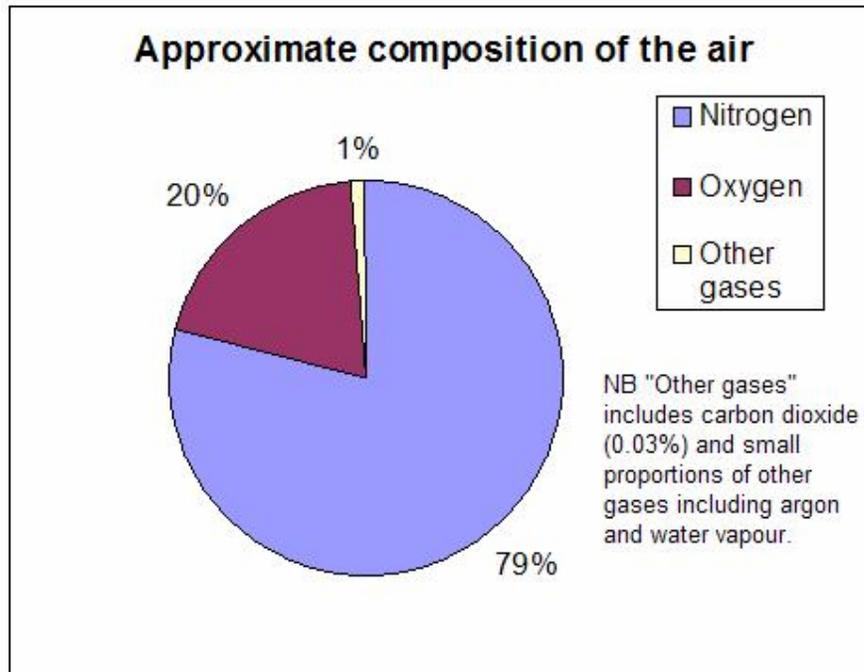


Figure 2: A satellite image of Vinson Massif - the highest mountain in Antarctica (Source: NASA)

**Why is less oxygen available to human beings when they are at elevation?**

**Oxygen makes up 21% of the Earth's atmosphere. Whether at sea level or at altitude this amount is fixed. If the percent of oxygen in air is constant, then why is there less oxygen available to human beings when we are at higher elevations? The explanation rests with the atmospheric or barometric pressure.**



**Figure 3: Composition of air (Source: Wikimedia Commons)**

**The air in which we live has a pressure. Basically the 'air', or more correctly the atmosphere is a big cloud of gas that surrounds the Earth. This gas is made up of molecules that have a weight and are pushing down on the surface of the Earth. The pressure this gas exerts is called atmospheric pressure. The air at the bottom of this cloud of gas, toward the ground, has all the air molecules above pushing down on it, and consequently is under the greatest pressure. As one moves higher in elevation the air has fewer molecules of gas pushing down on it from above and the air has a lower pressure. In other words as the altitude increases the atmospheric pressure decreases.**

**So, in Antarctica, as Ray, Richard and Kevin gradually travel upward from sea level at Hercules Inlet to ten thousand feet on the Antarctic Plateau, there will be steadily fewer air molecules pushing down on them from above and the atmospheric pressure will decrease. This decrease in atmospheric pressure will mean that less oxygen will be available to their blood streams. This is because the atmospheric pressure helps 'push' oxygen molecules**

**Did You Know?**

The Earth's rotation causes the atmosphere to bulge at the Equator and flatten at the poles – which causes a further pressure drop producing a physiologic altitude equivalent to 10,000 and 11,500 feet at the South Pole.

from the lungs into the blood stream. When there is inadequate oxygen in the blood stream of an individual it is called hypoxia.

A normal healthy human being at sea level carries about 97 to 99% of the maximum oxygen they can in their bloodstream. If you take that same individual and drop them at the South Pole the saturation of oxygen will fall to about 87 to 89% or even lower. They will likely notice this change by feeling dizzy, slightly short of breath with any exertion and get headaches. The higher one goes, the more the blood oxygen saturation will drop and the symptoms that can develop are more severe. At very high and extreme altitudes individuals can become seriously ill with fluid in the lungs (pulmonary edema) and on the brain (cerebral edema). Both of these conditions are very serious and not infrequently result in death. Immediate descent from altitude, and supplemental oxygen are the best initial treatment for these more severe forms of altitude sickness.



Figure 4: Altitude sickness warning sign at the Mount Evans observation area in Colorado (Source: Wikimedia Commons, [Shadowlink1014](#))

**Not all people are equally susceptible to altitude sickness. In fact why some people fall ill and other do not is a mystery. It is known that the following factors put you at risk of altitude sickness:**

- **Physical exertion**
- **Age less than 50 years**
- **Residence at an altitude less than 3000 feet**
- **Rapid rate of ascent**
- **Obese individuals**

**Unfortunately for Ray, Richard and Kevin many of the risk factors apply to them. They are all under fifty years of age, they all live at low altitude and will be exerting themselves for ten to fifteen hours a day as they head for the South Pole. However they will be gradually ascending to 10,000 feet over 35 days, and none are obese (even though they ate a great deal in Punta Arenas preparing for the expedition!). Nonetheless they were all confident setting out for the South Pole that as world class endurance athletes that they will acclimatize to the high altitude of Antarctica.**

**Knowing that they may experience difficulties with the oxygen deficient conditions on the South Pole Plateau, Ray, Richard and Kevin have been trying to ensure that they minimize supplies in order to diminish the weight of their sledges and limit the energy they must exert in pulling them. Fortunately, Ray, Richard and Kevin understand the principles of atmospheric pressure and recognize that they can take less cooking fuel to boil water than they would need if they stayed at sea level. This is because the temperature at which water boils is not in fact fixed at 100 degrees C, but is actually a function of the atmospheric pressure around the water. Water boils when the water vapor pressure is equal to the local atmospheric pressure. Thus water boils at a lower temperature when the atmospheric pressure is lower at higher elevation. So Ray, Richard and Kevin will need less cooking fuel as they rise up the Polar Plateau.**

#### **Did You Know?**

**That the human body acclimatizes to the decreased oxygen partial pressure at higher elevations by altering breathing function, heart output, pulmonary artery pressure, red blood cell production and urine output.**



**Figure 5: Plastic bottle crushed by change in atmospheric pressure when it was filled with air at a high elevation and carried to a lower elevation. (Source: David Monniaux)**



**Figure 6: A Barometer - for measuring atmospheric pressure (Source: Langspeed)**