



大屯火山群的今古傳奇

The Ageless Legend of Datun Volcano Group



位於陽明山國家公園內的大屯火山群，是台灣面積最龐大的火山群，也可能是台灣本島內唯一的活火山，汩汩湧出的滾熱溫泉、轟轟作響的火山噴氣，都暗示大屯火山群區域底下，擁有活動中的岩漿庫。亙古以來，大地的造山運動與火山活動，把地殼變動、地質演變的遞嬗故事，都寫在這裡，堪稱是一部活生生的地質史。

The Datun Volcano Group of Yangmingshan National Park is the largest volcano group in Taiwan and the only active volcano on the Taiwan Island. The boiling hot spring and scorching volcanic gas that gush out of the ground are both indications of an active magma chamber underneath this area. The tectonic and geological evolution of the earth are all recorded here through orogeny and volcanic activities in the past, leaving us a living geological history to study.

走入大屯火山群，每一座山稜都有令人讚嘆的火山地形美景，再多的字彙詞藻，都無法道盡她的美麗山容。

在地球遠古漫長的地質歷史中，岩漿因為板塊互相推擠、壓迫，而蠢動不安的從地表迸發噴出，一次又一次堆積、冷卻，再加上颱風的刮切、大雨的沖刷，塑造出大屯火山群現今的面容。

「大屯火山群還相當年輕！」研究台灣火山運動的台灣大學地質科學系教授宋聖榮，以沉穩的語氣道出大屯火山群的成因。他表示，台灣位於歐亞板塊與菲律賓板塊的交接縫合處，菲律賓板塊往西北方向的歐亞板塊俯衝，因歐亞板塊比重較小，造成菲律賓板塊的前端在板塊交界處，隱沒於歐亞板塊的下方。隱沒在大陸板塊下方的海洋板塊前端，由於所受的壓力與溫度逐漸升高，海洋板塊內的含水礦物開始發生脫水作用，產生比重小的含水流體往上遷移到這個「楔形地函」（也就是2塊板塊上下疊插的區域），促使地函的岩石圈在該地熱溫度下融熔，產生流質的岩漿。這股岩漿繼續上湧，岩漿內的氣體受到壓力的變化，會逐漸膨脹，隨著岩漿一起從板塊交接處的裂縫噴出地表，形成了大屯火山群。

年紀輕輕的活火山

根據陽明山國家公園的委託研究調查，顯示大屯火山群的噴發時間從280萬年前開始，直至20萬年前，甚至可能年輕於1萬年左右。在噴發的當時，大屯火山群所在的區域只是一片略高於海平面的丘陵地，來自地函的岩漿不斷地找裂縫口噴出，因而形成一座座大小不一的火山體、火山口，即是今日所見到的七星山、面天山、磺嘴山、竹子山、大油坑等火山地貌。

Within the Datun Volcano Group, every mountain is a spectacular scene of volcano topography and no human expression can possibly describe its beauty.

In the primitive eons of the earth's geological history, massive magma erupted out of the ground due to mutual pushing and pressing and then cooled down and heaped up repeatedly. The scraping and scratching by typhoons and erosion by rain helped to shape the accumulated magma into the present look of the Datun Volcano Group.

"The Datun Volcano Group is still fairly young," says Sheng-rong Song, Professor of Department of Geosciences of NTU, telling about the cause of the Datun Volcano Group in a steady voice. He points out that Taiwan is situated at where the Eurasian Plate and the Philippine Sea Plate meet. As the Philippine Sea Plate subducted northwest toward the Eurasian Plate, the tip of the former submerged beneath the latter which had a lesser specific gravity. The aquiferous minerals of the submerged part became dehydrated when the pressure and temperature rose gradually. Fluid with lesser specific gravity was produced and moved up to the cuneal mantle (where the 2 plates pile up), causing the rock sphere to melt under the geothermal heat and become liquid magma. When the magma rose upward, the gas inside it inflated with the change of pressure and erupted together with the magma through the fissure of the surface of the earth, and the Datun Volcano Group was thus formed.

A Youthful Active Volcano

According to the inspection made by Yangmingshan National Park, the eruption of the Datun Volcano Group started from 2.8 million years ago to 0.2 million years ago. At the first eruption, the site the Datun Volcano Group was simply a hilly land a little above the sea level. As the magma from the underground mantle kept looking for fissures to erupt, volcanoes and craters of different sizes were formed, i.e. the volcanic landforms constituted by Mt. Cising, Mt. Miantian, Mt. Huangzuei, Mt. Jhuzih and Dayoukeng.

前頁圖 FrontPage:

位於七星山鞍部的小油坑，是高溫火山氣體外洩的爆裂口。(楊志雄 攝)

Located at Anbu of Mt. Chishing, Siaooukeng is actually an opening for high-temperature volcano gas eruption. (by Mike Yang)

右頁圖 Right:

大油坑有一處硫氣口，擁有高約2公尺的硫磺結晶塔。(王漢棠 攝)

A 2m-tall cuneal crystal column of yellowish white color is formed at one fumarole at Dayoukeng. (by Wen-sung Wang)



從過去定年研究資料顯示，大屯火山群最後一回噴發的可信年代，是20萬年前。宋聖榮說，根據中研院地科所與經濟部中央地質調查所鑽探台北盆地岩心的結果，發現在12,000至15,000年前的松山層，有火山灰的沉積。火山灰裡有火山玻璃的成分，在自然界的地質中也只有火山岩漿快速冷卻才有辦法形成，因此，學界推估大屯山最近一次噴發的時間約可推演到1萬年前。

對人類而言，1萬年的時間距離相當悠久；但對45億歲的地球來講，只不過是瞬間的時差而已，「所以，大屯火山群還很年輕啊！」宋聖榮指出，台灣氣候多颱風大雨，千萬年來即使在風雨侵蝕下，大屯火山群依舊保有良好的火山地貌，就像年輕人能維持年輕面貌的道理一般。

地底的活動岩漿庫

大屯火山群的火山活動依然活躍，噴氣孔、溫泉、地熱景觀到處可見，不像鄰近的觀音山火山、基隆火山群，都已無火山活動而被宣告死亡，列為「死火山」。

過去學者定義活火山，是以人類文字歷史紀錄為參考，也就是說被人類紀錄到噴發狀況的火山，就是活火山；其他未有歷史紀錄的火山，則被列為休眠火山或死火山。

From age dating of research in the past, the reliable date of the last eruption of Datun Volcano Group is 0.2 million years ago. Professor Song says that the drilling through the core of Taipei Basin made by IESAS and Central Geological Survey, MOEA discovers volcanic ash deposit in the part of Songshan formation formed 12,000 to 15,000 years ago. The volcano ash contains volcanic glass that can be formed in natural geology only when the magma cools down drastically, therefore the academia estimate that the latest eruption of the Datun Volcano Group probably happened 10,000 years ago.

10,000 years may be a very long time for mankind, but it's merely a moment in a flash for the 4.5-billion-year-old earth. "So the Datun Volcano Group is still quite young!" As Professor Song explains, the reason why the volcanic landforms of the Datun Volcano Group remain rather intact while suffering frequent typhoons and rainstorms typical of Taiwan's climate is just the same as why a youth has a young look.

The Active Underground Magma Chamber

The volcano activities of the Datun Volcano Group are vigorous and alive with fumaroles, hot springs and geothermal landscapes seen everywhere. Quite on the opposite, its neighboring Guanyin Volcano and Keelung Volcano Group are both announced dead and labeled as "extinct volcanoes".

In the past, the academic definition of an active volcano used to refer to the written historical record of mankind, thus a volcano that has an eruption history recorded by mankind is active, whereas all other volcanoes without any recorded eruption are said to be dormant or extinct.

左頁圖 Left:

大屯火山群的熔岩流幾乎屬於安山岩質，含有鐵、鎂成分較多的黑色礦物結晶。(王漢棠攝)

Almost all the lava flow of the Datun Volcano Group is andesite that contains black mineral crystal of primarily iron and magnesium. (by Wen-sung Wang)

右頁圖 Right:

紗帽山是七星山西側小油坑內一個硫氣孔，周圍存在許多天然硫磺。(楊志雄攝)

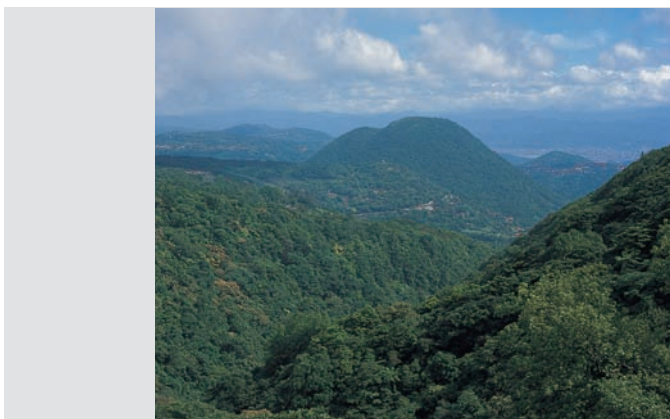
Shamao Mountain is sulfuric fumaroles in west of Mt. Chishing, and around many natural sulfur. (by Mike Yang)



「在人類紀錄中，最早記錄到的活火山是3,500年前的希臘與義大利火山，」宋聖榮指出，世界上有太多的火山在人類有紀錄前就已噴發，因此，後來國際火山學和地球內部化學協會提出一套經驗法則，用科學的方法判定火山噴發的年代，並把1萬年內（日本認定2,000年內）曾爆發過的火山，稱為活火山。

不過，這樣的經驗法則有先天上的不足，例如，1萬年前噴發的火山在風雨沖刷下，會把火山灰與火山碎屑侵蝕殆盡，現在可能已找不出噴發痕跡。國際火山學會在1994年同時也提出另外的活火山定義，採用現象法則定義，就是火山噴發需要靠地底下有岩漿才有辦法達到，因此若能利用科學方法偵測出火山地底下有活動中的岩漿庫，就可認定為活火山。

宋聖榮解釋說，地底若有岩漿庫，會在地表上反映出幾種現象：一是產生地震現象，因實體岩漿在地底下流動時，液體的岩漿與固體的岩圈互相擠動後，便會發生地震。二是當岩漿流往地表湧出時，會循著以往曾經隆起或噴發的火山管道上升，因此火山在爆發前，會開始隆起、膨脹。三是火山區域出現高溫的熱流，亦即岩漿的高溫會從地底傳熱上來，這從監測溫泉與地表熱流即可得知。最後是火山氣體增多，隨著岩漿往地表淺層移動，岩漿內的氣體會因壓力漸小，而造成氣體溶解度降低，釋放出火山氣體，氣體越多表示岩漿的活動越活躍。



“The earliest recorded volcano eruptions in human history are found in Greece and Italy 3,500 years ago.” Professor Song adds that since too many volcanoes had erupted long before any human record, IAVCEI later suggests a law of empiricism. According to this law, a scientific method is adopted to decide the date of a volcano eruption, and an active volcano is one that has erupted in 10,000 years (2,000 years according to Japan).

However, this empirical law may not suit for all cases. For example, the volcano ash and clastic deposit would be eroded by wind and rain and leave no trace of a volcano that erupted 10,000 years ago. Another definition of an active volcano according to the law of phenomenon proposed by IAVCEI in 1994 suggests that, since the eruption of a volcano depends on the underground magma, a volcano is active if any active magma chamber can be detected underneath it by scientific method.

Professor Song explains that several surface phenomena may be reflected by the underground magma chamber: the first phenomenon is earthquakes caused by the pushing and pressing between liquid magma and solid rock sphere when the former flows through underground. The second is the rise and swell of the volcano happening when the magma gushes upward to the surface via the conduits of a volcano that has previous rising and swelling records. The third is the high-temperature heat flux emitted from underground magma, and it can be detected by monitoring hot springs and surface heat flow. Finally it's the increasing volcano gas which moves with the magma toward the superficial bed of the earth. The volcano gas will be released as the solubility of the gas in the magma is lowered by high pressure. When there is more and more gas released, it means the magma has become increasingly active.

依據前述的現象所提，加上台大地質研究所與中研院連續7年針對檢測火山氣體中岩漿逸氣組成比例結果，似乎可將大屯火山群重新定義為活火山，而目前大屯火山群岩漿活動最活躍的地區，就在大油坑。

大油坑的火山活動現象

大油坑是昔日的產硫重地，採硫作業已停止，當地兩處的大型噴氣口依然轟隆作響地噴發出火山氣體。隨著火山氣體上升到地表的硫磺，結晶厚厚凝結在大油坑的噴氣口外，其中一座硫氣噴氣孔還形成高約2公尺、白黃色的錐狀硫磺結晶塔。

這2座噴氣孔所冒出的白茫的煙霧，有90%以上是水蒸氣，其餘是二氧化碳、二氧化硫、硫化氫等。「一點點的硫磺（二氧化硫），就會讓火山氣體充滿刺鼻的硫磺味。」宋聖榮說，所以大屯火山群有噴氣口的地方，都可以聞得到硫磺味。

「儘管種種科學研究結果暗示著，大油坑地底下有岩漿庫，但是有岩漿活動，並不表示會馬上噴發，這需要透過長期的監測才能預測，以目前監測數據顯示並無任何噴發的跡象，大家不用太過恐慌啦！」宋聖榮表示。

接著，宋聖榮從電腦裡調出大屯火山群的LiDAR影像圖，從這張使用雷射光束進行地面掃描測距的地形影像圖上，可以清楚看出區域內所有的火山地形裂口、火山體、熔岩台地等地形。

Based on the aforementioned phenomena as well as the inspections on the ratio between volcano gas and magma conducted by the Institute of Geology of NTU and Academia Sinica for successive 7 years, maybe the Datun Volcano Group can redefine as an active volcano. Currently Dayoukeng is the part with most active magma found within the Datun Volcano Group.

Volcano Activities of Dayoukeng

Dayoukeng was once an important place of sulfur production and now all mining operations have stopped, except that the 2 large fumaroles there are still fuming noisily. The sulfur surfaces above the ground together with the volcano gas and forms crystals near the margins of the fumaroles, and one of which even forms a 2-m-tall conical crystal column of yellowish white color.

90% of the white misty fume released from these 2 fumaroles is steamy vapor, and the rest comprises CO₂, SO₂, H₂S and other chemicals. “Just a little bit of sulfur (SO₂) can fill the volcano gas with pungent smell,” says Professor Song. Therefore every part of the Datun Volcano Group with fumaroles found will smell sulfur.

“According to scientific monitoring, it is true that there is magma underneath Dayoukeng, but that doesn’t mean the magma will soon erupt. It takes a long-term monitoring to make any prediction. However, there isn’t any sign of immediate eruption for the present. There’s no need to panic!” says emphatically Professor Song.

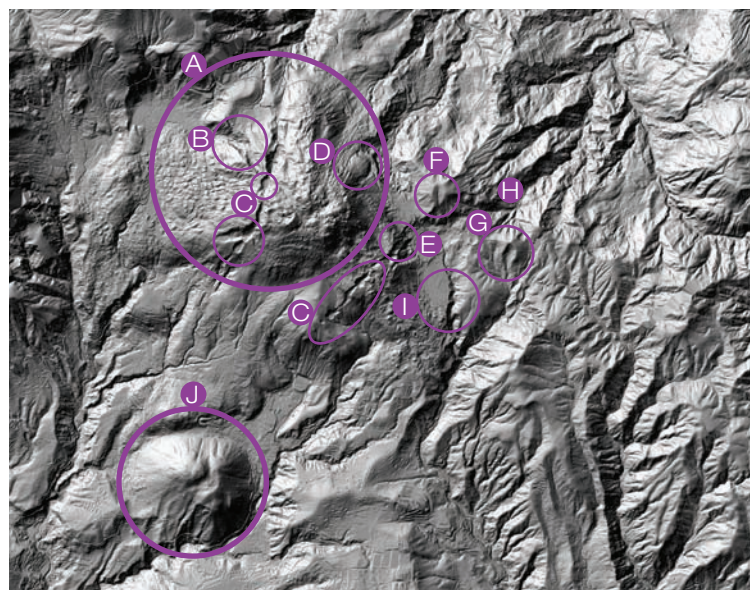
Then professor Song shows us a LiDAR image of the Datun Volcano Group from the computer file. On the topographic image made by scanning and determining distance to a surface with laser pulses, one can see clearly all the fissures of a volcano landform, the volcano bodies, lava plateaus and other landforms.

從爆裂口噴發出來的硫氣，直接昇華凝結在岩石表面，成為易碎的塊狀結晶體。(王漢棠 攝)
The sulfur gas erupts from the opening, sublimates on the rock surface and becomes fragile crystal nuggets. (by Wen-sung Wan)



LiDAR影像是這2年來台灣地質研究界引入最新的空拍技術，由空中向地面發射高頻率的雷射光束，利用發射脈衝到反射訊號之間的時間差，可以清楚探知地面建築物、植被與地形的三維坐標。宋聖榮說，「LiDAR可以直接把建築物、植被資料去除，呈現完整的地形面貌。從大屯火山群的LiDAR影像圖研判，夢幻湖與冷水坑之間有幾個火山爆發所形成的斷層裂隙，而造成夢幻湖漏水，這個斷層裂口應是原因之一。」

從一張張的LiDAR影像，慢慢還原出十萬、百萬年前的大屯火山群曾經發生過的故事。「這2年台灣的火山學因科學儀器的進步，而陸續出現火山偵測的新資料。」宋聖榮笑著說，靠著科學監測「從今窺古」，地質學者將會挖出更多、更精采的大屯火山群傳奇。



The LiDAR system is the latest method of aerophotography adopted by Taiwan geological studies in the past 2 years. Airborne high-frequency laser beams are shot from the air to the ground, and by measuring the time delay between the transmission of a pulse and the detection of a reflected signal we can determine the three-dimensional coordinates of the buildings, vegetation and the landforms. Professor Song says, "LiDAR can directly erase the information about the building and vegetation to exhibit a complete appearance of the landforms. Judging from the LiDAR image of the Datun Volcano Group, between the Menghuan Pond and Lengshueikeng there are several fault fissures caused by volcano eruption, and is the reason for the leak of the Menghuan Pond."

Various changes happened to the Datun Volcano Group millions of years ago have been gradually recovered by LiDAR images.

"Volcanology in Taiwan has gained a lot more new information about volcano detection thanks to the improvement of scientific apparatus in these 2 years," says Professor Song smilingly. By observing the present to learn about the past with the help of scientific monitoring and detection, geologists will discover more and more interesting stories about the Datun Volcano Group.

左圖 Left:
大屯火山群的LiDAR影像圖。
(宋聖榮 提供)
The LiDAR image of the
Datun Volcano Group. (by
Sheng-rong Song)

- A 七星山
Cising Mountain
- B 小油坑
Siaoyoukeng
- C 火山爆裂口
The Fissure of Volcano
- D 火山穹窿
Lava Dome
- E 夢幻湖
Menghuan Pond
- F 七股山
Chiku Mountain
- G 火山渣錐
Cinder Cone
- H 擎天崗
Cingtiangang
- I 冷水坑
Lengshueikeng
- J 紗帽山
Shamao Mountain

宋聖榮 小檔案 Sheng-rong Song



國立台灣大學地質學研究所理學博士、美國布魯克海汶國家實驗室訪問學者。
現任國立台灣大學地質科學系教授，專長為火山學、岩石學、地球化學。

Doctor of Science of Department of Geosciences, National Taiwan University, and once a visiting research fellow of Brookhaven National Laboratory, USA. He is now Professor of Department of Geosciences, National Taiwan University, specializing in volcanology, petrology and Geochemistry.