Chapter: Seven

Chapter 7
Summary and Conclusions

Study of subduction zone is a very active field of research as it is known as our planet's largest recycling system. The subducting slab delivers raw materials such as oceanic lithosphere along with oceanic sediments and seawater to the subduction factory, where these raw materials reequilibrate with ambient mantle, triggering melting to generate arc volcanoes and on a longer run creating continental crust on the overriding plate. In this context, the present study is an attempt to characterize the raw materials and understand the influence of subduction zone processes on mantle geochemistry and on the chemistry of magma generated close to and away from trench. Towards this, we selected Andaman Subduction Zone (ASZ) as our study area, which apparently has preserved all the morphological features expected in an intra-oceanic convergent margin. Additionally, the region is home to one of the youngest active arc systems and an accretionary wedge that is home to ophiolites which have physical continuation with the Naga–Himalayan-Oman ophiolites. The accretionary prism or wedge also contains numerous mud volcanoes that presumably trapped fluids and sediments from the slab-wedge interface and are examples of active fluid systems operating in subduction zones.

The thesis work was initiated with six specific questions as our objectives: I) to understand the origin of the subducting fluids; 2) to chemically characterize the subducting solid materials; III) to understand the subduction initiation process through the study of ophiolites of the accretionary wedge; IV) to characterize the arc volcanism and understand their petrogenesis; V) to determine the degree and depth of melting of the arc magmas, and VI) to understand how the chemistry of mantle wedge evolves through time due to the contributions from the slab. To provide

answers to these we had a field–experimental-theoretical modelling approach. Detailed fieldwork was done in Andaman Islands to recognize various members of the subduction zone and collect suitable material for experimental work.

Through field relationships and information from earlier work it was established that the ophiolites of the Andamans possibly represent *in situ* produced rocks and are not transported from a mid-oceanic-ridge. It was also established that there exist mud volcanoes on the accretionary wedge which are apparently connected to the decollament fault system, at the boundary between the subducting and overriding plates, through which gas, water and clay rich sediments are brought to the surface. Therefore, at the accretionary prism we had access to two major components for our study: the ophiolites and the mud volcanoes. In the arc-front we had access to a remote, young and active volcano called the Barren Island, which provided us with right materials to study the processes occurring in the mantle wedge. Rock and water samples from these geological features were studied for their chemistry (major, trace and isotope geochemistry) and theoretically modelled to understand their origin and evolution, and attempts were made to answer the main questions that we had asked at the beginning. In the following paragraphs we list our major conclusions and other inferences pertaining to the Andaman subduction zone:

I) Geochemical and isotopic data from the Andaman ophiolites clearly suggests that these rocks had multiple magma sources, which might have had different timing of emplacements. These rocks show both MORB and volcanic arc signatures and their chemistry rules out the possibility of them being generated at a mid-oceanic spreading centre. In stead, they have a suprasubduction zone origin, with the MORB type

ophiolites emplaced first during the initiation of subduction, followed by volcanic –arc type ophiolites – which have clear signatures from the slab.

II) Through our work we established that the mud volcanoes of Andaman accretionary wedge are indeed the plumbing systems that tap the subducting materials from the slab-wedge interface through a complex network of faults. The water that oozes out at these mud volcanoes are decompressed pore water released from clay minerals by dehydration at depths in excess of 2-4 km and at temperatures of 60-70°C. Petrography of mud breccia emitted by the mud volcanoes suggest that their clay matrixes are chlorite and kaolinite dominated –derived predominantly from the altered oceanic crust. Geochemistry including radiogenic isotopes in these clay clearly supports this inference and reveals that mud breccia are predominantly derived from the slab crust (70-80%) and carry the typical arc-type trace element signatures such as the depletions of Ta, P and Ti. The latter indicates that it could be the mud breccias that provide the above signatures to the mantle wedge and hence to the arc lavas. Some elements like Ba is also contributed to the mantle wedge by the mud breccia – but through the fluids. Isotopically the mud breccia has a mixed ratio (silicate + water) for $^{87}Sr/^{86}Sr$ (~0.7092) but have intermediate ε_{Nd} (-3.3 to -1.7) between that of the slab crust and the sediments. Thus, for the first time ever we have characterized the subducting components at a subduction zone.

III) For the first time ever, we have thoroughly mapped and chemically characterized most of the lava flows and ash beds on the Barren Island Volcano that represents the volcanic arc of the Andaman subduction zone. Based on the field relations and chemistry of the eruptions we could established that the islands had at least three major magma supplies leading to precaldera, post caldera and modern eruptions.

The precaldera eruptions appear to have been derived from a single batch of magma and have undergone extensive fractional crystallization, producing basalts and basaltic andesites with a large variation in their SiO_2 contents. Based on major element chemistry we have established that the lavas on Barren Island are predominantly tholeiite belong to high-Al_2O_3 and low to medium K magmas. Trace element contents of Barren Island volcanics are typical of island arc lavas and suggest that the parental magmas had little crustal contamination during their emplacement. Sr–Nd–Pb isotope systematics of the volcanics from the island reveal that this arc volcano is one of the most primitive in the entire chain with very little contribution from the slab material. Through theoretical modelling of the isotope and trace element data we have established that the precaldera lavas had appreciable (< 10%), although lower than normal arc magmas of contributing from the slab derived fluids, whereas slab derived sediments (< 15%) appear to have affected the chemistry of post caldera and modern lavas. It appears that the mantle source for the volcano during its initial stages had contributions from the slab mostly through fluids, and with time slab contribution appears to have shifted towards more sediment incorporation. With the help of melting models we could established that the precaldera lavas have been produced from magma that represent 5-15 % partial melts of the metasomatized mantle wedge, whereas the post caldera and modern lavas have been derived from magmas representing 5-10 % partial melts from the similar source. We have also been able to establish that the magmas for Barren Island were generated at depths where a garnet was stable - > 90km deep in the mantle wedge.

Apart from the above major findings we also have numerous other findings from this work, some of these are reported above.

i) For the first time ever we have introduced the 'Island Arc Group' into the stratigraphy of the Andaman and Nicobar islands, since these volcanic rocks have been ignored from all earlier classifications.

ii) We have produced an accurate topographic and geological map of Barren Island based on satellite imaginary and extensive field mapping done during four field trips to the island.

iii) We were the first to report the 2009-10 lava eruptions on the island that flowed into the sea along a completely different route than all earlier flows.

iv) For the first time ever we reported toothpaste lava flows from the island belonging to 1994-95 eruptions.

v) Through our study we have established that the rain, spring and ground waters of the region fall exactly on the Global Meteoric Water Line in the δD vs. $\delta^{18}O$ plot.

vi) We have also established that the water accompanies the mud breccias have lower $^{87}Sr/^{86}Sr$ than the silicate fraction and that it's the latter that affects the former.

Scope for future work

Recommendations regarding possible future work that could be undertaken in continuation of the present study are:

I) Ophiolites are considered to be important tools for understanding the tectonic and magmatic processes responsible for the formation of oceanic lithosphere. Due to lack of sufficient data, the

inference about the origin of rocks of Andaman ophiolites is still not well established. Based on few existing studies, it is believed that the origin of ophiolitic complexes of Andaman, Naga and Oman might have similar petrogenetic histories. The further comparative lithological and geochemical (major, trace elements couple with isotopic ratios) studies of these rocks can provide insights into the tectonic setting and many interesting aspects of the emplacement of these ophiolitic complexes.

II) In the absence of absolute and precise age of the lava flows of Barren Island (BI) Volcano, it is difficult to constrain the temporal changes in the lava flows on BI, so the geochronological attempts (U-Th dating, Ar-Ar dating) should be made to date volcanism on BI.

III) It has been observed that subducted sediments affected the mantle wedge beneath the Barren Island Volcano. In the connection Li isotopes are known as good tracer because the δ^7Li of altered oceanic crust is much higher at a given Li/Y compared to the mantle. The study along with measured Pb isotope systems which have elevated values with compare to mafic crust and mantle, will allow multiple source components to be resolved.

IV) In present study, our focus was mainly on Barren Island volcano; there is one more dormant subaerially exposed arc volcano in Andaman Sea known as Narcondam. It is believed that the lavas of this volcano suffered crustal contamination. So, the details study of lavas of this volcano should give clues to understand the affect crustal interference and also its effect of fractional crystallization of the lava flows. This will give to understand chemical evolution of lava in Andaman subduction zone.