The application of Raman spectroscopy as geothermometer for the sedimentary formation of Southern Yu Shan, Taiwan

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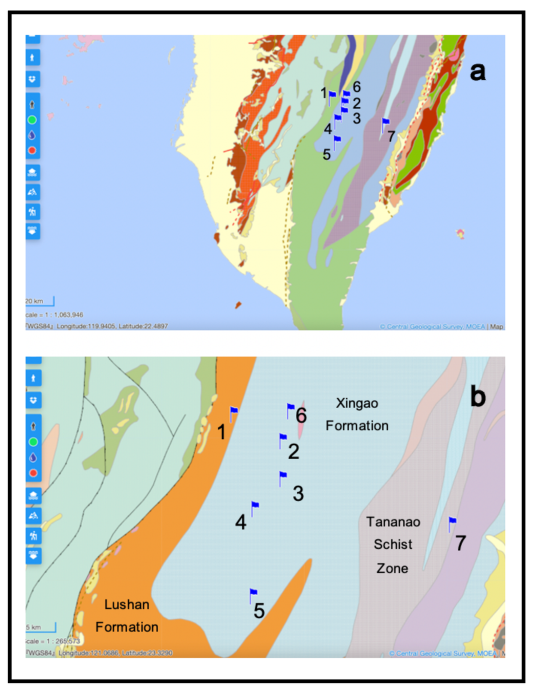
Introduction

Temperature evolution of a rock formation is crucial when we want to reconstruct an orogenic history. In this study, we are going to use Raman spectroscopy of carbonaceous material (RSCM) as a geothermometer to obtain estimation of peak temperature of low-grade metamorphism in the southern section of Yu Shan. By estimating the peak temperature, the depth of burial, amount of uplift and uplift rate can be estimated.

Method & Materials

Sample information:



Number on the map	Rock Unit	Sample Name	Longitude E	Latitude N	Location of sampling	Lithology
1	Lushan Formation	01SH113	120.850883	23.2584	Provincial highway no. 20. 113km	Hard shale
2		GS-1	120.91170	23.22782	Guan Mountain	Mudstone
3		HNNS-1	120.91138	23.18549	Hainuonan Mountain	Quartz sandstone
4		XGS-1	120.87702	23.15119	Xiaoguan Mountain	Mudstone
5	Xingao Formation	BNZS-1	120.87469	23.05167	Beinanzhu Mountain	Slate
5		BNZS-2	120.87469	23.05167	Beinanzhu Mountain	Meta-igneous rock
6		01SL138	120.92096	23.262263	Provincial highway no. 20, 138km	Slate
7	Tananao Schist	02XW	121.119928	23.133715	Beside Xinwu Bridge, 197km	Green schist
7		02XWQ	121.119928	23.133715	Below Xinwu Bridge,197km	Green schist

Fig. 1 Simplified geological map of the Southern Yu Shan in Taiwan (upper left); Closer view of the map (lower left); Information about the samples (right). Maps are taken from Geology Cloud.

Sample preparation: Large petrographic thin sections and automatic polishing with 1-3µm aluminium oxide powder.

Spectra acquisition and treatment:

- Renishaw InVia Qontor confocal Raman microscope, along with WiRE software for spectra measurement.
- 30-40 data points for each sample, exposure time 10 seconds, accumulations of 3.
- Deconvolution of spectra using Lorentz function in PeakFit 4.0, main two peaks will be separated into D1, D2, D3, D4 and G.
- Calculation of parameter RA1 and estimation of temperature for low-grade metamorphism using calibration formula by (Lahfid *et* al., 2010).

Discussion

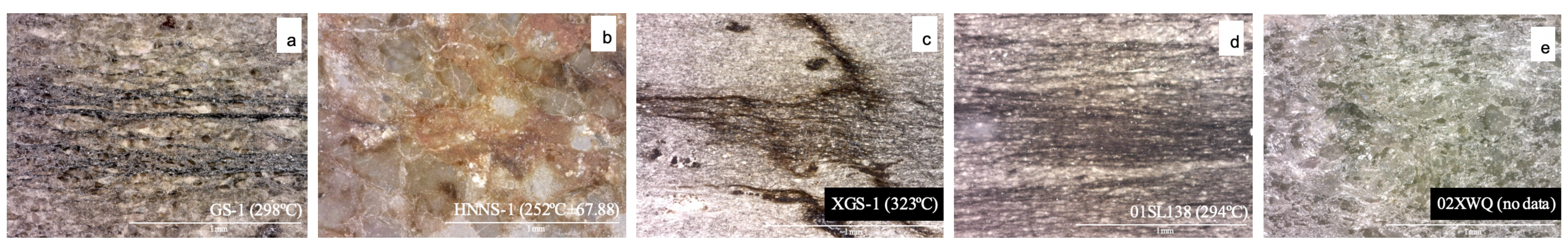


Fig.5 Microscopic photo of analyzed samples with magnification 200x. (a) Mudstone sample GS-1. (b) Quartz sandstone sample HNNS-1. (c) Mudstone sample XGS-1. (d) Slate sample 01SL138. (e) Green schist sample 02XWQ.

Spectra acquisition of sample HNNS-1 (Fig. 5(b)) and 02XWQ (Fig. 5(e)) shows that quartz sandstone and green schist are not suitable for RSCM analysis, as it doesn't contain enough carbonaceous material (CM). For RSCM analysis, it is preferable to use sample high in CM, which is typically indicated by darker color of the rock.

The area suitable for data points are also shown in Fig. 5(a), 5(c) and 5(e). The darker area of the rock indicates more abundant presence of CM in the particular area.

Rock Unit	Sample Name	Longitude E	Latitude N	Location of sampling	Lithology	T (°C)	Burial depth (km)	Current elevation (km)	Estimated uplift (km)	Minimum estimated uplift rate (mm/year)	Maximum estimated uplift rate (mm/year)
Lushan Formation	01SH113	120.850883	23.2584	Provincial highway no. 20, 113km	Hard shale	-	-	1.06	-	-	-
	GS-1	120.91170	23.22782	Guan Mountain	Mudstone	298	9.93	3.667	13.597	0.4	2.72
	HNNS-1	120.91138	23.18549	Hainuonan Mountain	Quartz sandstone	252	8.4	3.17	11.57	0.34	2.31
	XGS-1	120.87702	23.15119	Xiaoguan Mountain	Mudstone	323	10.77	3.24	14.01	0.41	2.8
Xingao Formation	BNZS-1	120.87469	23.05167	Beinanzhu Mountain	Slate	-	-	3.242	-	-	-
	BNZS-2	120.87469	23.05167	Beinanzhu Mountain	Meta-igneous rock	-	-	3.242	-	-	-
	01SL138	120.92096	23.262263	Provincial highway no. 20, 138km	Slate	294	9.8	2.44	12.24	0.36	2.45
	02XW	121.119928	23.133715	Beside Xinwu Bridge, 197km	Green schist	-	-	0.38	-	-	-
Tananao Schist	02XWQ	121.119928	23.133715	Below Xinwu Bridge,197km	Green schist	-	-	0.38	-	-	-
										Eocene (33.9Ma)	Taiwan orogeny ≤5Ma

Fig. 6 Sample information with burial depth and estimated uplift (km).

Assuming (1) the average continental geothermal gradient to be 30°C/km, burial depth and amount of uplift can be estimated. (2) the sediment was deposited not after the end of Eocene (33.9Ma), (3) the initial uplift of the sediment is not after the start of Taiwan orogeny (5Ma), the minimum & maximum uplift rate can be estimated.

Result

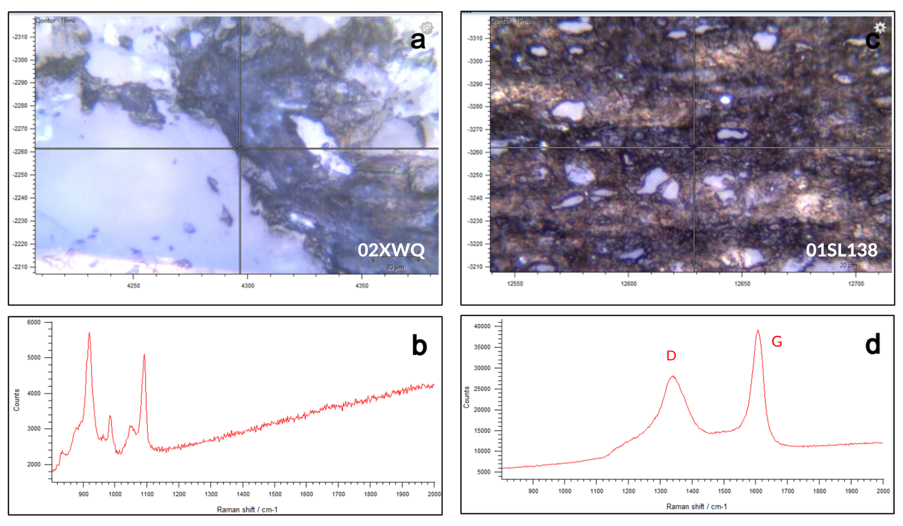


Fig. 2 Comparison between micro-scopic photo (magnification 500x) and spectra of greenschist sample 02XWQ (left) and slate sample 01SL138 (right). The slate sample shows first-order carbon spectra with two main peaks (D and G), while the green schist sample shows irregular spectra (non-carbon mineral).

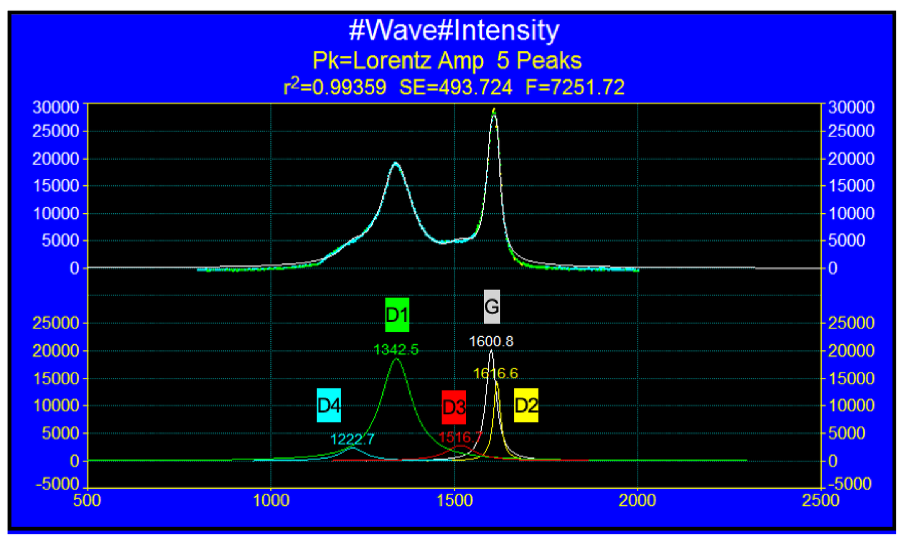
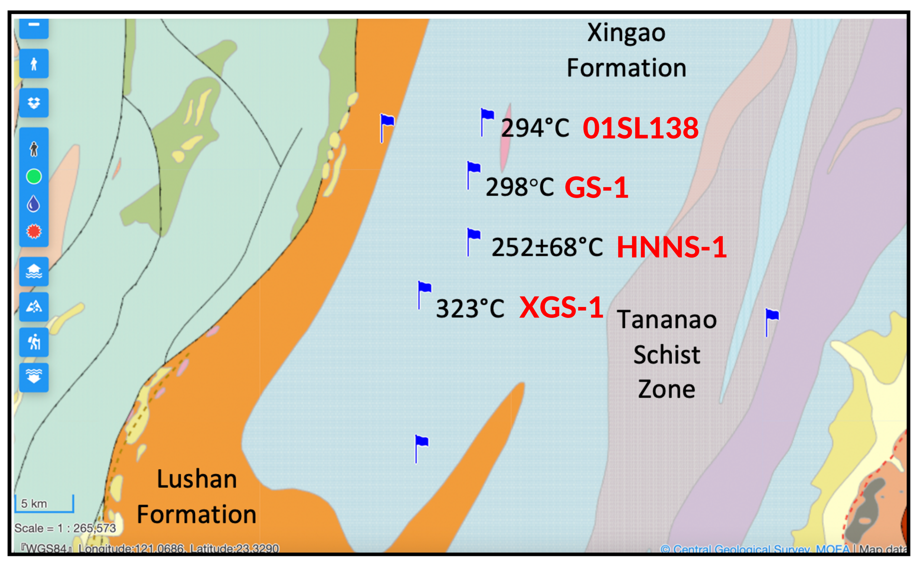


Fig. 3 Carbon spectra after deconvolution is separated into smaller peaks D1, D2, D3, D4 and G. The D4 intensity in this sample is stronger, which is characteristic of metamorphism with peak temperature below 330°C.



Rock Unit	Sample Name	Lithology	RA1 parameter Mean	RA1 parameter SD	Number of spectra	T (°C)
Lushan Formation	01SH113	Hard shale	-	-	-	-
	GS-1	Mudstone	0.6142	0.0036	23	298
	HNNS-1	Quartz sandstone	0.5771	0.0543	3	252
	XGS-1	Mudstone	0.6344	0.0036	19	323
Xingao Formation	BNZS-1	Slate	-	-	-	-
	BNZS-2	Meta-igneous rock	-	-	-	-
	01SL138	Slate	0.6127	0.004	37	294
Tananao Schist	02XW	Green schist	-	-	-	-
	02XWQ	Green schist	-	-	-	-

Fig. 4 Geological map showing RSCM-T results (left); RSCM temperature RA1 data of samples. SD: Standard deviation. Error of temperature <5°C, except for the sample HNNS-1 where data is not sufficient.

Conclusion

- Maximum temperature of metamorphism of the studies samples is around 300°C, with burial depth about 10km and uplifted to 3km above the sea level.

- The minimum and maximum estimated uplift rate are between 0.038cm/year and 0.257cm/year.

- RSCM method is applicable for this study, but not to all rock types. It generally works with darker rock that contain abundant CM, such as slate or mustone. However, it doesn't work for quartz sandstone or greenschist due to the lack of CM in this type of rock.

Acknowledgement

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Appendix Reference

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