

**Dating blueschist-facies metamorphism within the Naga ophiolite,
Northeast India, using sheared carbonate veins**

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ABSTRACT

The tectonic significance of blueschist-facies rocks associated with the Indo-Myanmar
ophiolite belt is uncertain, given their lack of detailed petrological study and the paucity of

reliable age data for different stages in their geological evolution. Here, we present new integrated petrological and geochronological data for samples from the Nagaland complex of the Indo-Myanmar ophiolite belt, northeastern India, which constrains the pressure–temperature conditions and absolute ages of peak and retrograde metamorphism. Several samples of blueschist were collected from the region, which have been variably deformed and subjected to shear recrystallization. Based on microstructural constraints and mineral geochemistry, garnet, omphacite, barroisite, chlorite and muscovite are interpreted to represent a high-pressure prograde-to-peak metamorphic assemblage, and omphacite, actinolite, hornblende and albite represent a lower-pressure retrograde metamorphic assemblage that formed during shear-related exhumation. Petrological modelling and thermobarometry indicates that unsheared samples equilibrated at ~1.9 GPa and ~~~420–560~~ °C ~~~480–520 °C~~ (**LARGE T RANGE AT FIXED P EXPLAINED IN THE TEXT**) at peak metamorphism, indicating subduction to ~60 km depth, whereas sheared and recrystallised samples re-equilibrated at ~0.6 GPa and ~470 °C (**EXTREMELY PRECISE P-T RANGE INSTEAD**) during retrograde metamorphism associated with obduction of the Naga ophiolite onto the Indian foreland. U–Pb *in-situ* analysis of carbonate grains (aragonite–calcite) ~~and associated silicate phases (epidote, prehnite, amphibole etc.)~~ in different microstructural positions, including within dynamically recrystallised shear bands that cross-cut older metamorphic fabrics and cogenetic silicate phases, constrains the age of peak metamorphism to be c. 95 Ma and retrograde metamorphism to be c. 90 Ma. Based on the overall progression of ages in the sheared and unsheared samples, we interpret that the area experienced ~~atypically slow~~ exhumation at a time-averaged rate of ~1 cm/year ~~in the order of Phanerozoic period plate tectonic rate~~ (**ARE YOU SURE THIS CAN BE CONSIDERED A SLOW EXHUMATION RATE? TO MY KNOWLEDGE, RATES IN THE ORDER OF MM/YR ARE ALSO COMMON, SEE E.G., MANZOTTI ET AL., 2008,**

~~CORRECTED~~), which is in the order of rates of plate tectonic processes on the Phanerozoic Earth

1. Introduction

High-pressure metamorphic belts provide a critical record of the geological evolution of paleo-plate boundaries, and provide valuable constraints on tectonothermal models of both modern and ancient ~~orogenesis~~ **orogeneses** (e.g. Ernst 1973; Carswell 1990). Blueschist-facies rocks form at high-pressure–low-temperature (~~HTP–LPT~~) metamorphic conditions characteristic of subduction zones (Miyashiro 1961; Cloos 1985; Palin and White 2016) or ephemerally in the embryonic stages of collisional orogeny (Wang and Foley, 2020), where they may subsequently recrystallize to greenschists or amphibolites under higher temperatures and/or lower pressures (Ernst 1973). Combining mineral equilibria constraints on the thermobarometric conditions under which sequential assemblages formed with absolute ages obtained via *in-situ* geochronology, can elucidate the timing and timescales of geodynamic processes that control the subduction–exhumation cycle (e.g. Terry *et al.* 2000; Rubatto and Hermann 2001; St-Onge *et al.* 2013).

The power of this integrated technique is demonstrated here ~~using the example of~~ **in the case of** the Indo-Myanmar ophiolite belt, a part of the Indo-Myanmar Range that extends to the east and southeast of the Himalayan orogen. The geological history and tectonic evolution of this belt is currently poorly understood, such that more precise constraints on the pressure–temperature–time (P – T – t) path of key lithologies ~~from the complex~~ are necessary to improving our geological understanding of this part of southeast Asia. Much of the current uncertainty concerning the tectonic evolution and significance of these Indian-plate ophiolitic rocks stems from a lack of reliable petrochronological data. In particular, the timing and P – T conditions of high-pressure metamorphism in the Indo-Myanmar belt is poorly constrained

75 due to the general absence of datable mineral phases in mafic igneous rocks that are reactive
76 at subsolidus subduction-zone HP–LT metamorphic conditions. Zircon from jadeitites in this
77 region have previously ~~produced~~ yielded U–Pb ages ranging from Late Jurassic (c. 147 Ma:
78 Shi *et al.* 2008) to Late Cretaceous (c. 77 Ma: Yui *et al.* 2013), although all of these data
79 show significant scatter due to incomplete recrystallization of magmatic grains and
80 metasomatic/hydrothermal activity during subduction and exhumation, which can partially
81 reset isotope systems (Wang and Griffin 2004). Furthermore, these former studies performed
82 geochronology on zircon grains separated from the host rocks, which ~~prohibits~~ inhibits direct
83 correlation of age data with P – T conditions derived from metamorphic assemblages and
84 microstructures, leading to potentially unreliable geological interpretations.

85 The zircon U–Pb isotope system is widely applied for dating the crystallization and re-
86 crystallization of mineral assemblages during high-temperature metamorphic events (e.g.
87 Williams and Claesson, 1987; Parrish, 1990; Robb *et al.* 1999, Rubatto *et al.*, 2001). However,
88 some lithologies and/or geological processes often cannot be dated directly by this technique
89 due to the absence of appropriate minerals that incorporate measurable amounts of radiogenic
90 nuclides. Examples of such rocks can be found in shear zones, ~~such as mylonites and tectonic~~
91 ~~carbonates~~, but this issue also extends to HP–LT metamorphic rocks, ore mineralisations,
92 diagenetic minerals and cements, some sedimentary rocks, and some alteration assemblages
93 (e.g. Gilley *et al.* 2003). Recent studies have focused on the application of *in-situ* U–Pb isotope
94 analyses of low-U minerals (~~e.g., carbonates, epidotes, amphiboles etc.~~) in thin section by laser
95 ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) for geochronological
96 study (Millonig *et al.* 2012; Coogan *et al.* 2016; Ring and Gerdes 2016; Roberts and Walker
97 2016; Li *et al.* 2014). Thus, instead of dating single accessory mineral domains, millimetre-
98 sized minerals and mineral assemblages (e.g., carbonate, epidote, amphibole etc.) that
99 recrystallised and equilibrated during a single tectonic event and which contain measurable

amounts of U and Pb can be used to determine crystallization ages (e.g. Burisch *et al.* 2017; Ring and Gerdes 2016).

~~According to Rasbury and Cole (2009), a linear regression taken through a group of samples from the same system produces a slope from which an age can be calculated using the accepted decay rate for the parent isotope. If the system being analysed has no initial heterogeneity, and it remained closed throughout the duration of the decay process, all scatter of data points about the isochron can be explained by analytical uncertainties. A statistical test of this is the mean squared weighted deviate (MSWD). Closed isotopic systems will plot as a line, giving a precise age and low mean squared weighted deviate (MSWD) of ~1, while systems that have not remained closed will show scatter and have a high MSWD ($\gg 1$). Here we apply this~~ the isochron method to dynamically recrystallised carbonate veins and selected mineral assemblages (amphibole, epidote) in blueschists within the Kiphiere District of the Nagaland ophiolite belt and integrate these ages with thermobarometric data to produce new constraints on the timing and rates of subduction and exhumation of Neo-Tethyan crust in the Indo-Myanmar region.

2. Geological background

The Indo-Myanmar Range is thought to represent a relict eastward-dipping subduction zone that runs from the eastern edge of the Himalayan Range in southeast Tibet to the island of Sumatra in the south (Allen *et al.* 2008; **Fig. 1**). The Eastern Himalayas, about 700 km long, trends ENE-WSW. Broadly N-S trending to sigmoid IMR has subdivided into three sectors from north to south of about 400 km length each e.g., Naga Hills, Chin Hills and Arakan Yoma (Acharyya 2015). The belt continues as the Anadaman Nicobar island arc in the south. Belts of narrow tectonised but nearly continues, late Mesozoic-Eocene ophiolite and associated sediments skirt along the northern margin of the Himalayas (Indus-Tsangpo

125 **Ophiolite-ITO) and the eastern margin of the Himalayas IMR.** Structural relationships show
 126 that Indian-plate oceanic crust was overridden by units of the **West Burma Block (ANY**
 127 **INFORMATION ABOUT THESE? JUST A FEW NOTES ABOUT E.G.,**
 128 **LITHOLOGY, TECTONIC SIGNIFICANCE ETC. WOULD BE USEFUL)** (e.g. Holt *et al.*
 129 *al.* 1991; Mitchell *et al.* 2007; Searle *et al.* 2007), although its age of formation and the
 130 timing of its obduction are poorly known. The Indo-Myanmar ophiolite belt separates
 131 subducted Indian-plate oceanic lithosphere to the west from a closely associated high-
 132 pressure metamorphic belt and Jurassic to Cretaceous magmatic arc–forearc complex of the
 133 Burmese plate to the east (Mitchell *et al.* 2012). The Naga Hills ophiolite **is represented by**
 134 **peridotite, cumulate mafic-ultramafic, mafic volcanics, eclogite, glaucophane schist,**
 135 **amphibolite and late felsic intrusives. The ophiolite sequence has an east-dipping thrust**
 136 **contact with the underlying flysch-like sediments of the Disang and Barail Formations**
 137 **exposed to the west, and are overthrust from the east by continental metamorphic rocks of the**
 138 **Naga Metamorphics consisting of quartz mica-schist, garnet mica-schist, quartzite, and**
 139 **granitic gneiss (Brunnschweiler, 1966). The mid-Cretaceous, fossil-bearing Nimi Formation**
 140 **occurs at the contact between the ophiolite and the Naga Metamorphics (Chatterjee and**
 141 **Ghose, 2010).** Within this belt, blueschist- and eclogite-facies rocks (SOME
 142 **INFORMATION ABOUT THESE ROCKS, ARE THESE MAFIC? CARBONATIC?) occur**
 143 as tectonic slices (or detached layers and lenses) intercalated with **unmetamorphosed**
 144 **(MAYBE YOU SHOULD explicitly mention THIS, OTHERWISE IT MIGHT SOUND**
 145 **A LITTLE BIT ODD, SINCE ALSO BLUESCHISTS AND ECLOGITES ARE MAFIC**
 146 **ROCKS, DONE)** mafic and ultramafic units. Basement lithologies underlie Palaeogene
 147 sediments in the ophiolite belt, although their geological history and lithological constitution
 148 are uncertain (Acharyya 2015). Ophiolitic rocks within the Indo-Myanmar belt have been
 149 subdivided into two parallel groups: the **(I AM NOT SURE THEY DISPLAYED IN FIG.**

1, AS I THINK THEY SHOULD) ‘Eastern’ and ‘Western’ belts (Mitchell 1993), although both show similar structural and petrological characteristics. Accretion of the Eastern Belt, which contains metamorphosed ultramafic rocks in northern Myanmar that host world-famous jadeitites, is thought to have occurred sometime after the Mesozoic (Gansser 1980; Mitchell 1993; Shi *et al.* 2008). The Western Belt along the Naga and Manipur hills, which forms part of the Indo-Myanmar Range, formed due to collision between India and the Burmese microplate during the late Oligocene (Sengupta *et al.* 1990).

There is still controversy about emplacement ages of ophiolites in these two belts: the ‘Eastern Belt’ is inferred to mark the locus of the subduction zone into which the ophiolites were accreted since Mesozoic, whilst the ‘Western Belt’ was inferred to have been caused by a late Oligocene terminal collision between the Indian and the Burmese continental blocks (Shi *et al.*, 2014 and references therein). In the ‘Western Belt’ a combination of radiolarian biostratigraphy and whole-rock K–Ar geochronology suggests an Upper Jurassic age (Kimmeridgian–Lower Tithonian) for marine sedimentation and volcanism in the **(YOU DID NOT MENTION WHETHER THIS BELONGS TO WESTERN OR EASTERN BELT DONE – NOW MENTIONED AT THE START OF THE SENTENCE)** Nagaland ophiolite belt (Sarkar *et al.* 1996; Baxter *et al.* 2011). The mid-Cretaceous, fossiliferous Nimi Formation occurs at the contact between the ophiolite and the Naga metamorphic units, and so gives a maximum age constraint on the initiation of obduction. Recently, Singh *et al.* (2017) reported U–Pb zircon ages ranging between 116 and 119 Ma from the plagiogranite **(YOU DID NOT MENTION THE OPHIOLITE SEQUENCE EARLIER, THIS IS THE FIRST TIME ONE READ ABOUT THIS PLAGIOGRANITE UNITS? WHICH I THINK IT IS NOT A GOOD IDEA. MAYBE YOU MIGHT WANT TO INCLUDE FEW NOTES ABOUT THE STRUCTURE OF THE NAGALAND OPHIOLITE BEFORE THIS DESCRIPTION OF THE AVAILABLE GEOCHRONOLOGICAL**

DATA? DONE) of the studied ophiolite. In the 'Eastern Belt' falling in the Mynamar Shi *et al.* (2008) reported a sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon age of 146.5 ± 3.4 Ma from for jadeitites of the Jade Mines area, Myanmar, and suggested proposed that subduction may have begun during the Late Jurassic. Mitchell (1993) suggested that the Manipur ophiolitic nappe was emplaced along the Indo-Myanmar ranges during the Mid-Eocene and was followed by a switch to east-dipping subduction from the mid-Miocene onwards. Recently, Liu *et al.* (2016) reported a c. 125 Ma U–Pb zircon crystallisation age for rodingite associated with formation of the ophiolite, and a c. 115 Ma age from for garnet amphibolites that may date metamorphism within the Kalaymo ophiolite belt, which lies adjacent to the Indo-Myanmar ophiolite belt. Shi *et al.* (2014) reported superimposed tectono-metamorphic ages (NOT SURE ABOUT BY THESE SUPERIMPOSED TECTONOMETAMORPHIC AGES, MAYBE YOU SHOULD ELUCIDATE A LITTLE, we are reporting the ages as interpreted by Shi *et al.*, 2014 and cannot elucidate any further than the conclusions provided in that work) of phengitic mica Ar-Ar ages from blueschist-facies rocks in the Tagaung-Myitkyina Belt. They interpreted a Jurassic age (152.4 ± 1.5 Ma) obtained from glaucophane (DID YOU MENTION THAT THEY DATED PHENGITIC MICA, they have analysed both the phengite and glaucophane) as the lower limit of the subduction age and suggested that Eocene (45.0 ± 1.3 Ma) (OBTAINED IN WHAT KIND OR MINERAL PHASE, DONE) ages recorded an intra-continental shearing deformation event.

Chatterjee and Ghose (2010) documented eclogite- and blueschist-facies (AGAIN ANY INFORMATION ABOUT THE LITHO-TYPE, DONE) rocks present as thrust slices and lenses within the volcanic and ultramafic rocks of the Naga ophiolite belt complexes (IS THIS THE SAME AS NAGALAND OPHIOLITE BELT? PLEASE NOTE THAT EVEN THOUGH THIS MIGHT SOUND ABSOLUTELY OBVIOUS TO

YOU, THIS IS NOT THE CASE FOR A READER WHO IS NOT FAMILIAR WITH
 THE LOCAL GEOLOGY (AS I AM), TO WHICH ALL THESE FOREIGN NAMES
 SOUND NEW AND POSSIBLY CONFUSING, **DONE**). Ao and Bhowmik (2014)
 deduced the thermal history of the eclogite and blueschist rocks ranging from ~~~11.5 kbar~~ **1.15**
~~6 kbar~~ **GPa** and ~340 °C to ~~6 kbar~~ **0.6 Gpa** and 335 °C. Despite an improved understanding of the
 tectonic evolution of the Indian ophiolite belt, a paucity of reliable geochronological age data
 (I AM NOT SURE ABOUT THIS IS EVIDENT FROM WHAT YOU REPORTED
 ABOVE, YOU MENTION NUMEROUS AGE DATA, WHICH MIGHT SOUND
 PERFECTLY RELIABLE IF YOU DO NOT EXPLAIN WHY DO NOT CONSIDER
 THEM SO. MAY BE YOU MIGHT ADD SOME MORE SPECIFIC COMMENTS
 ABOUT THIS, EXPLAINING WHY THE DATA IS AT LEAST QUESTIONABLE. I
 AM SURE THIS WILL HELP THE READER (ESPECIALLY THE non-expert ONE)
 TO UNDERSTAND WHAT IS THE POINT OF STRENGTH OF YOUR NOVEL
 APPROACH TO SUCH TOPICS, **DONE**) has hindered the correlation of sutures and
 collisional deformation episodes within the region (AGAIN I AM AFRAID THAT IF YOU
 DO NOT PROVIDE SOME ADDITIONAL DETAILS (POSSIBLE WITH SOME
 EXAMPLES), IT IS NOT COMPLETELY CLEAR WHAT ARE THE PROBLEMS
 HERE. PLEASE NOTE THAT IS A RATHER GENERAL STATEMENT THAT
 MIGHT APPLY VIRTUALLY TO ANY CASE STUDY. SO I WARMLY INVITE
 YOU TO INCLUDE SOME ADDITIONAL DETAIL. I AM NOT SAYING YOU
 SHOULD MAKE A THOROUGH REVIEW ABOUT THESE ISSUES BUT SIMPLY
 ADD SOME INFORMATION ABOUT E.G., THE MOST PROBLEMATIC POINTS
 OF DEBATE THAT MIGHT BENEFIT FROM THE RESULTS OF YOUR WORK)

3. Analytical methods

225 The eclogites and blueschists rocks of Naga Hills occur as NE–SW to N–S oriented, steeply
226 east-dipping shear fault-bound tectonic slices or detached layers and lenses intercalated with
227 basaltic and ultramafic units parallel to the shear faults in the Naga Hills ophiolite of Phek
228 district, Nagaland (Chatterjee and Ghose, 2010). In the area eclogite constitutes the core of
229 some lenses, which are surrounded by successive layers of garnet-blueschist, glaucophanite
230 and greenschist. Twenty metamorphosed samples were collected between Longkhimong and
231 Moya villages, after systematic petrographic study six samples were selected for detailed
232 study. Mineral compositional data for all samples (**YOU NEVER DESCRIBED THESE**
233 **EARLIER IN THE TEXT. I THINK IT WOULD BE BETTER TO FIRST EXPLAIN**
234 **WHAT KIND OF SAMPLES WERE INVESTIGATED, AND THEN HOW. MAYBE**
235 **YOU CAN ADD SOME NOTES ABOUT THE SAMPLING ACTIVITIES,**
236 **INCLUDING LOCATIONS, STRATIGRAPHIC POSITIONS, LITHOTYPES,**
237 **NUMBER OF COLLECTED SAMPLES ETC. DONE**) were obtained on a JEOL JXA-
238 8200 electron microprobe housed at the Institute of Geosciences, Johannes-Gutenberg
239 University of Mainz, Germany. Operating conditions included an acceleration voltage of 15
240 kV, a beam current of 12 nA, and a 2 µm spot size. A matrix correction for atomic number
241 (Z), absorption (A), and fluorescence (F) was automatically applied to all analyses. For the
242 data presented below, mineral compositions were recalculated to standard numbers of
243 oxygens per formula unit (pfu) using the software AX (Holland 2009), with OH assumed to
244 be present in stoichiometric amounts. The proportion of ferric iron in different mineral
245 species was also calculated using the software AX (~~Holland 2009~~). Mineral proportions for
246 each sample were determined using the software JmicroVision (Roduit 2010), with each
247 individual count consisting of five hundred points randomly distributed over a digitally
248 scanned thin-section image. Calculated volume proportions (**HOW HAVE THIS BEEN**
249 **CALCULATED? I THINK YOU SHOULD SPECIFY THIS, ALSO CONSIDERING**

THAT YOU DID NOT JUST MAKE A MODAL BY SIMPLE POINT COUNTING.
THEREFORE, I THINK IT IS ABLUTELY NEVESSARY TO EXPLAIN HOW DID
YOU MAKE THIS KIND OF CALCULATION) of minerals in each sample are given
below. These bulk compositions are given in Supplementary Table 3. ~~Mineral proportions for~~
~~each sample were determined using the software JmicroVision (Roduit 2010), with each~~
~~individual count consisting of five hundred points randomly distributed over a digitally~~
~~seanned thin-section image.~~ Mineral abbreviations are after Kretz (1983). Representative
(WHY ONLY SOME REPRESENTATIVES? YOU CAN INCLUDE ALL YOUR
DATASET IN THE ESM – ~~we believe that providing all data in electronic appendices~~
~~offers no significant benefit from providing representative examples. This is our preferred~~
~~style for data presentation and indeed it is commonplace in petrological studies to only show~~
~~representative examples.)~~ compositions of major minerals for all samples are given in
Supplementary Table 2 and photomicrographs of microstructural features and assemblages
are shown in Figs. 2 and 3.

Bulk-rock compositions for use in petrological modelling were obtained from X-ray
fluorescence (XRF) via the production of glass ~~beads~~ **(IS THIS CORRECT? TO MY**
KNOWLEDGE, YOU CAN HAVE “PRESSED POWDER PELLETS”, BUT FUSED
SAMPLES ARE REFERRED TO AS ‘GLASS BEADS’ PLEASE CHECK ~~DONE~~) in
order to guarantee standardised and reproducible analyses. Powdered rock samples were
initially dried overnight at 105 °C. Approximately 5.2 g of lithium tetraborate ($\text{Li}_2\text{B}_4\text{O}_7$) flux
and 0.4 g of powdered rock sample were then weighed, homogenized, and melted in a Vulcan
AMA melting device to produce each glass ~~beads~~ **(HERE AND IN THE FOLLOWING:**
AS IN THE PREVIOUS COMMENT, PLEASE CHECK IF ‘PELLET’ IS
APPROPRIATE). These ~~beads~~ were then analyzed in a Philips MagXPRO spectrometer
with a rhenium X-ray tube housed in the Institute of Geoscience, Johannes Gutenberg

University of Mainz, Germany. Detection limits are estimated to be $100 \mu\text{g g}^{-1}$ for light elements (Na, Mg, Al) and $10 \mu\text{g g}^{-1}$ for heavy elements (K to U). Analysed major oxides comprised SiO_2 , Al_2O_3 , total Fe_2O_3 , MnO, MgO, CaO, Na_2O , K_2O , TiO_2 , P_2O_5 , SO_3 , Cr_2O_3 , and NiO.

All U–Pb ages **for the analysed carbonate grains and silicate phases** were acquired *in situ* from polished thin sections by laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) at the Goethe University Frankfurt (GUF), using a Element2 (Thermo-Scientific) sector field ICP-MS coupled to a RESOLUTION ArF Excimer laser (Compex Pro 102). The applied method was similar as described in Ring and Gerdes (2016), Burisch *et al.* (2017), Hansman *et al.* (2018) and Salih *et al.* (2019). Ablation spot size was $213 \mu\text{m}$ and crater depth was $\sim 20 \mu\text{m}$. Samples were screened by LA-ICP-MS for suitable Pb and U concentration and variability, and selected spots were subsequently analysed in fully automated mode. Spot analyses consisted of 20 s background acquisition followed by 20 s sample ablation. Surface contamination was removed prior to each spot analysis via a 3-s pre-ablation. Soda-lime glass SRM-NIST 614 was used as a reference material together with two carbonate reference materials – WC-1 and a Zechstein dolomite – to bracket sample analysis. SRM-NIST 614 yielded a depth penetration of about $0.5 \mu\text{m s}^{-1}$ and an average sensitivity of $280,000 \text{ cps}/\mu\text{g g}^{-1}$ for ^{238}U . The detection limits for ^{206}Pb and ^{238}U were ~ 0.1 and 0.05 ng g^{-1} , respectively. All data were corrected using an MS Excel spreadsheet program (Gerdes and Zeh, 2006, 2009). NIST 614 was used as a standard for the analysis of silicate phases **(SO YOU ANALYSED SILICATE PHASES ALSO? THIS IS NOT WHAT IS REPORTED IN THE ABSTRACT. PLEASE ELUCIDATE, DONE)**. The possible offset related to sample matrix is within the analytical uncertainty of the quoted ages.

The $^{207}\text{Pb}/^{206}\text{Pb}$ ratio was corrected for mass bias (0.3%) and the $^{206}\text{Pb}/^{238}\text{U}$ ratio for inter-element fraction (ca. 5%) using SRM-NIST 614. An additional correction of 4% was

applied on the $^{206}\text{Pb}/^{238}\text{U}$ to correct for difference in the fractionation due to the carbonate matrix. This resulted in a lower intercept age of 23 WC-1 spot analyses of 254.1 ± 1.5 (MSWD = 1.5; anchored at $^{207}\text{Pb}/^{206}\text{Pb}$ of 0.851) and 253.9 ± 3.4 (MSWD = 1.5; $n = 17$) for the Zechstein dolomite used as an in-house reference material in Frankfurt. Data were plotted on a Tera-Wasserburg diagram and ages calculated as lower intercepts using Isoplot 3.71 (Ludwig 2007). All uncertainties are reported at the 2 sigma level.

According to Rasbury and Cole (2009), a linear regression taken through a group of samples from the same system produces a slope from which an age can be calculated using the accepted decay rate for the parent isotope. If the system being analysed has no initial heterogeneity, and it remained closed throughout the duration of the decay process, all scatter of data points about the isochron can be explained by analytical uncertainties. ~~A statistical test of this is the mean squared weighted deviate (MSWD).~~ Closed isotopic systems will plot as a line, giving a precise age and low **mean squared weighted deviate (MSWD) of ~1**, while systems that have not remained closed will show scatter and have a high MSWD ($\gg 1$).

4. Sample petrology

Out of the twenty collected samples we have selected four metabasite samples for systematic study and thermobarometry. Six metabasite samples were collected from (AS SAID IN A PREVIOUS COMMENT, I THINK THAT GENERAL INFORMATION ABOUT THE INVESTIGATE SAMPLES SHOULD BE REPORTED IN THE TEXT. ALSO YOU SAY THAT YOU COLLECTED 6 SAMPLES, BUT IN THE FOLLOWING SECTION IT SEEMS TO ME THAT YOU ARE DESCRIBING ONLY 4 OF THEM: THE UNSHEARED N5 AND 14 AND THE SHEARED 7C AND 11. PLEASE ELUCIDATE) around Moya and Longkhimong (Fig. 1C) to place constraints on the metamorphic and deformational history of the Nagaland ophiolite belt. Locality information and GPS co-

ordinates for each outcrop are given in Supplementary Table 1 and location map is presented in Fig. 1C. Field photographs of the studied samples are presented in Fig. 1D. The samples occur as meter-sized boulder blocks, which occur individually and in clusters (Fig. 1 D1, D3) within serpentinites. Samples are thus classified as either sheared and/or unsheared based on the occurrence of key deformational features present at the field, hand sample, and microscopic scale. Samples N5 and 14 lack evidence of post-peak shear-driven recrystallization and likely represent relics of undeformed, peak metamorphic blueschists. By contrast, samples 7c, 13, 3b, and 11 are strongly sheared and represent subsequently deformed equivalents of these older units.

4.1. Sample description

4.1.1. Unsheared samples N5 and 14

Unsheared samples N5 and 14 exhibit a largely unfoliated microstructure and show no evidence of pervasive retrogression following peak blueschist-facies metamorphism during subduction, though localised retrogression does occur. Sample N5 is a blueschist that contains abundant sodic amphibole (38%) and epidote (37%), with minor quartz (9%), garnet (6%), sodic-calcic amphibole (4%), phengite (3%), and rutile (2%). Accessory pyrite, zircon, and apatite ($\ll 1\%$) also occur. Garnet porphyroblasts are between 0.5 and 2 mm in diameter (Figs. 2a–b) and exhibit no substantial major element compositional zoning, with core compositions of $\text{Alm}_{56-58}\text{Prp}_{12-14}\text{GrS}_{21-22}\text{Sps}_{7-8}$ and rim compositions of $\text{Alm}_{60-61}\text{Prp}_{15-16}\text{GrS}_{22-23}\text{Sps}_{3-4}$ (Supplementary Table 2 and Fig. 4). Core regions contain inclusions of pumpellyite, phengite, epidote, barroisite, actinolite, and quartz, and rims contain inclusions of phengite, epidote, actinolite, rutile, and quartz. Some grains show replacement by chlorite at their outermost rims. Matrix phengite contains $\text{Si} = 3.34\text{--}3.38$ pfu (on a 11 O basis; Supplementary Table 2) and grains included in the outer rims of garnet contain $\text{Si} = 3.32\text{--}$

3.35 pfu. Epidote shows no significant compositional zoning from core to rim, with a minor range in pistacite content ($\{XPs = Fe^{3+}/(Al^{3+}+Fe^{3+})\}$) of 0.18–0.21 (Supplementary Table 2). According to the classification scheme of Hawthorne *et al.* (2012), sodic and sodic-calcic amphiboles in the matrix are glaucophane and winchite–katophorite, respectively (Fig. 5).

Sample 14 is modally dominated by epidote (50%) and quartz (35%), with lesser garnet (1%), sodic-calcic amphibole (10%), phengite (2%), rutile (0.5%), ~~sphene~~–**titanite** (0.5%), and carbonate (**1%**) (**BASED ON SUCH MINERALOGY, HOW CAN YOU CONSIDER THIS TO BE A BLUESCHIST (METABASIC) ROCK? ALSO PLEASE NOTE THAT SUM OF THE LISTED MINERALS IS 101%** We follow the definition of Ernst (1963) in that a blueschist defined by the presence of the minerals glaucophane + (lawsonite or epidote) +/- jadeite +/- albite or chlorite +/- garnet +/- muscovite in a rock of roughly basaltic composition). Accessory minerals include chlorite, apatite, and zircon (all <<1%). Although sample 14 ~~contains~~ **displays** no foliation, it is mildly anisotropic, with alternating centimetre-scale quartz- and epidote-rich domains. In contrast to the large porphyroblasts present in sample N5, garnet forms <0.1 mm diameter grains that are restricted to quartz-rich regions (Fig. 2). These garnet grains have no inclusions and are compositionally homogeneous ($Alm_{36-39}Prp_{10-13}Grs_{31-36}Sps_{36-39}$) (**VERY DIFFERENT FROM SAMPLE N5, FURTHER HIGHLIGHTING THAT THIS CANNOT BE CONSIDERED SAME ROCK TYPE AS THE REPIUOS, IN MY OPINION** we do not consider this the same rock type. it is simply grouped here with 14 due to it being unsheared. the degree of deformation is the primary discriminator in this work.). Epidote shows no significant zoning, with core and rim compositions both having similar pistacite contents of 0.20–0.24 (Supplementary Table 2). Matrix rutile is partially or fully replaced by titanite (Fig. 2), though rare inclusions in sodic-calcic amphibole lack such pseudomorph textures. Phengite contains $Si = 3.34-3.35$ pfu (~~for~~ ~~11 oxygens~~; Supplementary Table 2) and in places is intimately intergrown with chlorite,

though the extremely fine-grained nature of these intergrowths prohibited reliable compositional analysis of either phase. Sodic-calcic amphibole in the matrix is barroisite–winchite–katophorite (Hawthorne *et al.* 2012; Fig. 5), with rare tremolite, likely representing minor post-peak retrograde mineralogical transformation.

~~Most natural carbonate occurs in the form of calcite and can be transported to the Earth's interior via subduction of carbonate-rich sediments or metasomatized oceanic crust (Zhang *et al.* 2018). Calcite transforms to aragonite at high pressure. Although may revert back to calcite during exhumation if there are no kinetic limitations. At the *P–T* conditions of peak metamorphism for samples N5 and 14 (see below), the carbonate likely stabilised in the form of aragonite, whereas carbonate in sheared samples 11 and 7c is calcite, which indicates polymorphic transformation following exhumation from peak depths (IN MY OPINION, THIS IS NOT APPROPRIATE FOR A SAMPLE DESCRIPTION SECTION LIKE THIS IS. I THINK IT SHOULD BE MOVED TO THE DISCUSSION SECTION. ALSO, I WOULD SUGGEST ADDING A FEW REFERENCES FOR THE GENERAL STATEMENT ABOUT CARBONATE MINERALS AND ON CALCITE/ARAGONITE TRANSITIONS AT THE BEIGINNING OF THIS PIECE OF TEXT.)~~ Analysed spots are presented in Supplementary Figure 5.

4.1.2. Sheared samples 11 and 7c

In contrast to N5 and 14, (SO YOU THINK THAT SAMPLES N5 AND 14 ARE MINERALOGICALLY HOMOGENEOUS? I FRANKLY CANNOT AGREE WITH IT, SINCE ONE IS BASICALLY GLN+EP, THE OTHER IS EP+WTZ. I THINK YOU SHOULD CAREFULLY RE-CONSIDER THIS The confusion here emanates from poor wording, which we have corrected. We do not think that both samples are similar (mineralogically) or homogenous – just that they are unsheared. The text has been modified

accordingly.) sheared samples 11 and 7c contain distinct spaced foliations that are truncated by carbonate- and quartz-filled veins. These crosscutting veins commonly form shear bands (Fig. 3e–f) and locally deflect the main metamorphic foliations at their boundaries (Fig. 3b), indicating that shearing and vein formation post-dated subduction metamorphism. The host rock domains in sample 7c are dominated by epidote (39%), calcic amphibole (32%), and sodic–calcic amphibole (18%), with minor ~~phengite–muscovite~~ (4%), albite (2%), K-feldspar (2%), titanite (1%), and quartz (2%). Apatite and zircon occur as accessory phases (**PLEASE NOTE THAT SUM OF THE PHASES LISTED ABOVE IS ALREADY 100% these are simply rounding issues and accessory phases, by definition, have very minor volumetric proportions. if we are to round the volume of the accessories to the nearest integer, they would have 0% volume anyway, leaving a total of 100%.**). The main metamorphic foliation is defined by elongate and aligned crystals of epidote and amphibole (Fig. 3a). Large green calcic amphibole is mostly pargasite with thin magnesiohornblende outer rims, and sodic-calcic amphibole is winchite (Fig. 5). Matrix ~~muscovite~~ **phengite** has $Si = 3.39–3.43$ pfu and epidote cores have $XP_s = 0.19–0.25$ and rims have $XP_s = 0.26–0.33$ (Supplementary Table 2). Quartz- and carbonate -filled veins crosscut and offset this epidote- and amphibole-defined metamorphic foliation (Fig. 3b).

Sample 11 contains abundant sodic amphibole (33%), quartz (34%), carbonate (14%), and sodic pyroxene (11%), with subsidiary sodic–calcic amphibole (2%), ~~muscovite~~ **phengite** (1%), garnet (2%), and albite (1%). Accessory pyrite, titanite, apatite, and zircon (all $<<1\%$) also occur. Alternating sodic amphibole (glaucophane) and quartz-rich bands define a spaced foliation that wraps around porphyroblasts of pyroxene and garnet (Fig. 3c). Grains of the latter are commonly less than 1 mm in diameter and are variably replaced by aggregates of carbonate, albite and/or quartz (Fig. 3d). Though individual grains lack any significant major-element compositional zoning from core to rim, compositions vary significantly between

grains; the majority are spessartine-rich ($\text{Alm}_{19-24}\text{Prp}_{10-14}\text{Grs}_{17-20}\text{Sp}_{845-51}$), while others are richer in almandine and grossular ($\text{Alm}_{26-29}\text{Prp}_{12}\text{Grs}_{23-32}\text{Sp}_{828-37}$). Minor sodic-calcic amphibole in the matrix is winchite, and sodic pyroxene porphyroblasts are compositionally classified as aegirine–augite ($\text{XJd} = 0.04\text{--}0.23$) (**GIVE JADEITITE COMPONENT**) (Morimoto *et al.* 1988).

5. Thermobarometry/Phase equilibria modelling (MAY BE A DIFFERENT NAME LIKE E.G., “PHASE EQUILIBRIA MODELLING” WOULD BE MORE APPROPRIATE, DONE)

Constraints on the P – T conditions of peak subduction-zone metamorphism were obtained from unsheared samples N5 and 14, whereas constraints on the P – T conditions of subsequent ductile shearing were obtained from **sheared** sample 7c (**WHAT ABOUT THE OTHER SHEARED SAMPLE 11? WHY YOU DID NOT USE THIS HERE? I THINK YOU SHOULD ADD SOME EXPLANATION**). Preliminary investigation of phase equilibria stability in sample 11 did not allow for reliable thermobarometry to be performed due to the high variance of the interpreted peak mineral assemblage. Phase diagrams showing the P – T conditions over which equilibrium mineral assemblages are calculated to occur in a specific bulk-rock composition (pseudosections) (**SINCE YOU ARE USING BULK ROCK COMPOSITIONS HERE I THINK YOU SHOULD ADD A SECTION ABOVE IN WHICH ROCK COMPOSITIONS ARE PRESENTED AND DESCRIBED, AT LEAST A LITTLE BIT. THIS IS NECESSARY ALSO TO UNDERSTAND WHY DID YOU CHOOSE THAT SPECIFIC MODEL SYSTEM. This is unnecessary – the petrological modelling community has well-defined compositional systems for use in modelling particular protoliths (e.g. metabasalts). These are constrained by the available a-x relations rather than the mineralogy of the rocks themselves.**) were constructed using

THERMOCALC v3.40i and the internally consistent thermodynamic data set ds55 (Powell and Holland 1988; Holland and Powell 1998; updated to August 2004) in the Na₂O–CaO–K₂O–FeO–MgO–Al₂O₃–SiO₂–H₂O–TiO₂–O (NCKFMASHTO) compositional system. The following activity–composition relations for solid-solution phases were used: clinoamphibole (**WHAT IS THE SOURCE FOR THIS**) (calcic, sodic-calcic, and sodic amphibole; Diener and Powell 2012), clinopyroxene (diopside and omphacite, Diener and Powell 2012), muscovite and paragonite (Coggon and Holland 2002), talc and epidote (Holland and Powell 1998), chlorite (Holland *et al.* 1998), biotite and garnet (White *et al.* 2007), plagioclase and K-feldspar (Holland and Powell 2003), ilmenite and hematite (White *et al.* 2000). Albite, lawsonite, rutile, titanite, quartz, kyanite, and H₂O were treated as pure phases.

5.1. Metamorphic mineral equilibria modelling parameters

Bulk-rock compositions used for modelling were obtained via XRF analysis, as discussed previously (Supplementary Table 2) (**THIS IS GETTING TORTOUS. IN THE ANALYTICAL TECHNIQUES SECTIONS YOU SAID YOU ACTUALLY DETERMINED BULK ROCK COMPOSITIONS VIS XRF ANALYSES. SO WHY YOU DID NOT USE THEM? NOT EVEN MENTIONING THAT IN THE ‘ANALYTICAL METHOD’ SECTION YOU EXPLICITLY REPORTED THAT ‘BULK-ROCK’ COMPOSITION FOR USE IN PETROLOGICAL MODELLING WERE OBTAINED FROM X-RAY FLOURESCENCE (XRF)’ (LINES 168-169). IN ADDITION, YOU REFER TO SOME SORT OF CALCULATION FOR OBTAINING MINERAL ABUNDANCES, SO I AM WONDERING IF THE ‘MINERAL PROPORTIONS’ INDICATED HERE ARE ACTUALLY MODAL PROPORTIONS (I.E., DETERMINED DIRECTLY, VIA POINT COUTING) OR RATHER WERE CALCULATED IN SOME SORT OF WAY (WHICH NEEDS TO BE SPECIFIED). PLEASE CAREFULLY ELUCIDATE ALL THIS. AFTER GOING THROUGH THE**

MANUSCRIPT, I'VE NOTICED THAT THE RESULTS OF XRF ANALYSES ARE NEVER EVEN REPORTED IN THE ELECTRONIC APPENDIX. ALL THIS IS DEFINITELY NEEDS TO BE CLARIFIED – **this was an unfortunate typo, we apologize for the confusion. XRF data were used.**) These bulk compositions are given in Supplementary Table 3. Mineral proportions for each sample were determined using the software JMicroVision (~~SO FINALLY, THE MODAL PROPORTIONS TURN OUT TO BE DETERMINED (NOT CALCULATED) VIA POINT COUNTING. I THINK THIS SHOULD BE SAID MUCH EARLIER, IN THE ANALYTICAL TECHNIQUES SECTION.~~) (Roduit 2010), with each individual count consisting of five hundred points (~~(ARE YOU SURE THESE ARE SUFFICIENT? TO MY KNOWLEDGE, YOU NEED TO HAVE MUCH MORE POINTS (3-4 THOUSANDS) IN ORDER TO CONSIDER YOUR MODAL ANALYSIS STATISTICALLY RELIABLE.)~~) randomly distributed over a digitally scanned thin section image (**NOT CLEAR TO ME: IS THIS IMAGE COVERING THE ENTIRE THIN SECTION AREA, OR JUST A PART OF IT? I GUESS (AND HOPE) THE SECOND, BUT MAY BE IT WOULD BE USEFUL TO EXPLICITLY MENTION THIS – point counting was applied to the entire thin section image, aside from areas that do not actually contain pieces of the rock (e.g. as it is not a perfect rectangle).** 500 points were sufficient in this case, as we kept track of the evolving proportions during analyses and the values converged on final results after ~300 points or so; thus, adding an extra 500 or 1000 points onto this initial 500 will produce no better precision.). For sample 7c, areas adjacent to shear bands were excluded from consideration during point counting such that the proportions obtained represent unsheared portions of the sample that equilibrated prior to deformation.

~~Although Schmidt and Poli (1998) suggest that seafloor hydrated metabasites can contain up to 5–6 wt.% H₂O, prograde metamorphism during subduction results in the~~

~~breakdown of hydrous phases such as chlorite, epidote, and amphibole, leading to progressive~~
~~dehydration and fluid loss from the local environment (e.g. Guiraud *et al.*, 2007, Hernandez-~~
~~Uribe *et al.*, 2020)~~ (THIS IS COMMON KNOWLEDGE. I DO NOT THINK IT IS
 NECESSARY TO REPORT IT. MOREOVER, I DO NOT THINK IT APPROPRIATE
 IN THIS SECTION, WHERE I EXPECT TO SEE ONLY INFORMATION ABOUT
 HOW YOU PERFORMED YOUR MODELS - ~~deleted~~). The effective fluid contents of
 for each bulk rock composition during metamorphism were calculated using the proportions
 of hydrous phases present in each equilibrium mineral assemblage, assuming H₂O was
 present in stoichiometric amounts. Mixed-component fluids were not considered due to the
 lack of reliable a-x relations for C–O–H fluids at elevated pressures (NOT SURE ABOUT
 WHAT YOU MEAN WITH THIS. WHAT ARE THESE ‘RELIABLE C-O-H FLUIDS’
 THAT LACK AT ELEVATED PRESSURES? DO YOU MEAN MODELS FOR
 SUCH KIND OF FLUIDS” PLEASE ELUCIDATE. ~~done~~); nonetheless, however, this
 should not have any significant effects on our calculated diagrams, as ~~unsheared~~ sample N5
 does not contain carbonate, ~~unsheared~~ sample 14 contains only a minor proportion (2.2 vol.
 %), and carbonate veins in sheared sample 7c are interpreted from microstructural constraints
 to post-date final metamorphism and textural equilibration. Pressure uncertainties for
 assemblage field boundaries are approximately ~~±1 kbar~~ 0.1 GPa (Powell and Holland 2008;
 Palin *et al.* 2016). ~~Calculated *P–T* pseudosections for each sample are given below.~~

5.1.1. Unsheared samples

~~The range of mineral parageneses and microstructural features in each sample allows *P–T*~~
~~constraints to be placed on peak metamorphism and exhumation-related ductile shearing.~~
 Calculated mineral assemblages matching those observed in unsheared samples N5 and 14 (I
 THINK IT WOULD BE MUCH BETTER IF YOU PRESENT THE RESULTS FOR

THESE TWO SAMPLES SEPARATELY. THEN YOU SHOULD PROPOSE A SINGLE P-T RANGE BY COMPRAING THEM AND SEE WHERE THE BEST MATCHES FOR BOTH SAMPLES OVERLAP. We disagree – we are grouping samples together according to whether they are sheared or unsheared.) constrain peak P – T conditions of subduction-zone metamorphism to ~1.8–2.0 GPa and ~420–560 °C, with the calculated proportions and compositions of major minerals best matching (THIS IS A VERY VAGUE CONCEPT. I MEAN, HOW DO YOU EVALUATE WHICH ONE IS THE BEST MATCH? GENERALLY SPEAKING, I GUESS YOU CAN SAY THIS IS THE ONE MINIMIZING THE DIFFERENCES BETWEEN THE OBSERVED AND CALCULATED MINERAL ABUNDANCES, BUT MAY BE THIS CAN DONE IN SOME OTHER WAY LIKE, E.G., MINIMIZING THE SQUARED RESIDUALS OF THE DIFFERENCES, OR MAY BE EVEN IN SOME OTHER WAYS. IN ANY CASE I THINK YOU SHOULD EXPLICITLY REPORT WHAT WAS YOUR STRATEGY, ALONG WITH ALL THE OTHER INFORMATION WHICH CAN HELP THE READER FIGURING OUT WHAT WAS DONE.) observed values at ~1.9 GPa and ~480–520 °C. These conditions lie along the global range of P – T conditions predicted to occur at the surface of subducted oceanic crust in modern-day subduction zones (Syracuse *et al.* 2010; Penniston-Dorland *et al.* 2015).

5.1.2. Sheared sample (STILL WONDERING WHY SAMPLE 11 WAS NOT USED FOR SUCH MODELS) Preliminary inspection did not reveal it to be useful or thermobarometry – not all rocks are useful, and this is a trial and error procedure that cannot be easily predicted ahead of time.

In contrast with the undeformed samples, the observed mineral assemblage in sample 7c was calculated to be stable at the notably lower pressure and slightly lower temperature conditions

of ~0.2–0.6 GPa and ~420–490 °C, with observed and calculated mineral proportions and
 compositions matching best at ~0.6 GPa and ~470 °C. ~~These P – T conditions are far removed~~
~~from the slab top range for modern-day subduction reported by Syracuse *et al.* (2010). The~~
~~calculated pressures of ~1.9 GPa for peak metamorphism and ~0.6 GPa for retrograde~~
~~equilibration are approximately equivalent to depths of 60 km and 15 km, respectively,~~
~~assuming no significant tectonic overpressure~~ (MAY BE THIS IS MORE APPROPRIATE
 IN THE DISCUSSION SECTION. HERE YOU SHOULD SIMPLY PRESENT THE
 RESULTS OF YOUR MODEL. ALSO NOTE THAT THES DEPTH ESTIMATES
 REFER NOT ONLY TO THE SHEARED SAMPLES, THE SUBJECT OF THIS
 PARAGRAPH BUT ALSO TO THE UNSHEARED ONES, THE SUBJECT OF THE
 PREVIOUS PARAGRAPH (I.E., SO WHY NOT REPORTING DEPTH ESTIMATES
 IN THE FORMER PARAGRAPH FOR THESE LATTER ONES?). Semi-independent
 constraints on P – T conditions using the avPT function of THERMOCALC (MAYBE YOU
 SHOULD EXPLAIN A LITTLE BIT WHAT IS THIS, SO THAT READERS THAT
 ARE NOT FAMILIAR WITH ALL THE OPTIONS OF THE THERMOCALC
 SOFTWARE CAN UNDERSTAND WHAT IS THIS FUNCTION AND WHY IT
 COULD BE USED TO TEST THE RESULTS FROM PSEUDOSECTION. JUST A
 FEW BRIEF NOTES COULD BE SIFFICIENT. AS FAR AS I KNOW, THIS
 SHOULD BE FOR MULTIPLE-REACTION THERMOBAROMTRY, BUT I HAVE
 TO SAY THAT I AM NOT SURE YOU CAN CONSTRAIN BOTH P AND T WITH
 THE SAME MODEL. HOW ABOUT CONSTRAINING P AND T
 INDEPENDENTLY, USING TWO DIFFERENT MODELS BASED ON MULTIPLE
 REACTION EQUILIBRIA? TO MY KNOWLEDGE, THERMOCALC SHOULD
 HAVE ALSO AVP AND AVT FUNCTIONS, EXACTLY FOR SUCH PURPOSES. The
 avPT function is well known in metamorphic petrology community and is well documented

in the source papers. We find the reviewer's comments inconsistent, whereby they ask us to remove some descriptions for being too obvious, but ask other descriptions to be added for things that we also perceive as being 'obvious'.) for each sample produced similar and statistically robust results of 2.05 ± 0.22 GPa and 489 ± 39 °C for N5, 1.95 ± 0.18 GPa and 541 ± 34 °C for 14, and 0.60 ± 0.23 GPa and 464 ± 76 °C for 7c (Supplementary Table 4) (SEE/ HERE YOU REPORT VALUES FOR SAMPLE N5 AND VALUES FOR SAMPLE 14 SEPERATELY. SO WHY NOT PRESENTING PSEUDOSECTION RESULTS FOR THE TWO SAMPLES SEPERATELY ALSO (AS ASKED IN A PREVIOUS COMMENT)?) See previous note of grouping samples according to their deformation history., corroborating the results obtained by phase diagram modelling.

6. U–Pb geochronology

U–Pb isotopic analysis of carbonate grains was carried out on metabasite samples 14 (unsheared), 11 (sheared), 3b and 13 (SO ARE THESE THE MISSING TWO SHEARED SAMPLES? I THINK THESE SHOULD BE TREATED EXACTLY AS THE OTHER SAMPLES (I.E., REPORT PETROGRAPHY, MINERAL CHEMISTRY, WHOLE ROCK COMPOSITION AND PERFORM THERMOBAROMETRIC MODELS), UNLESS, FOR SOME REASON THIS CANNOT BE DONE. BUT IN THIS LATTER INSTANCE, YOU SHOULD GIVE FULL EXPLAINATION ABOUT THIS), which equilibrated at different stages of the subduction–exhumation cycle. Carbonate crystals within dynamically recrystallised veins were preferentially selected for analyses; however, suitable matrix minerals were also investigated in order to perform a check on the analysed carbonates, which generally have a low U content. Results of the isotopic composition of the Nagaland blueschists are presented in Supplementary Table 5 and isochrons are shown in Fig. 9. Measured $^{207}\text{Pb}/^{206}\text{Pb}$ ratios range from 0.205 to 0.836 (sample 3b), 0.735 to 0.848 (sample 13), 0.776 to 0.845 (sample 11) and 0.809 to 0.846 (sample 14), and measured $^{238}\text{U}/^{206}\text{Pb}$

ratios range from 0.361 to 9.752 (sample 3b), 0.043 to 10.53 (sample 13), 0.118 to 5.474 (sample 11) and 0.809 to 0.846 (sample 14), as shown in Figs. 9a, b, c and d. All data for each sample lie on a single array on an isochron diagram, indicating that each attained isotopic equilibrium, and give well-defined least squares fit indices with MSWD values of 0.35–1.17 (Fig. 9). The U concentrations in the minerals range between 0 and 3 ppb and model Th/U ratios show a wide variation, with most lying between 0.015 and 5, but some reaching up to ~46. Results of the isotopic composition of the Nagaland blueschists are presented in Supplementary Table 5 and isochrons are shown in Fig. 9. These analyses show that unsheared samples 14 and 11 equilibrated at 95.3 ± 5.9 Ma and 93.7 ± 4.0 Ma, respectively, and sheared samples 3b and 13 experienced exhumation-related shear deformation at 90.6 ± 3.4 Ma and 88.8 ± 2.7 Ma, respectively. Although the unsheared sample dataset is within uncertainty of all the sheared sample dates, an overall age progression may be reconstructed from the sheared and unsheared samples. Considering the well-behaved dataset in the studied samples with a low MSWD, it can be broadly inferred that the analysed phases had the same initial isotopic ratio and that the system was at equilibrium during closure of the isotopic system.

7. Discussion and implications

Most natural carbonate occurs in the form of calcite and can be transported to the Earth's interior via subduction of carbonate-rich sediments or metasomatized oceanic crust (Zhang *et al.* 2018). Calcite transforms to aragonite at high pressure. Although may revert back to calcite during exhumation if there are no kinetic limitations. At the *P–T* conditions of peak metamorphism for samples N5 and 14, the carbonate likely stabilised in the form of aragonite, whereas carbonate in sheared samples 11 and 7c is calcite, which indicates polymorphic transformation following exhumation from peak depths. Analysed spots are presented in Supplementary Figure 5.

The tectonothermal evolution of the Indo-Myanmar Tethyan ophiolite belt is poorly understood owing to a lack of integrated thermobarometry and geochronology. Here, we have combined microstructurally constrained U–Pb data with P – T conditions calculated for peak and retrograde metamorphism in order to constrain the exhumation history of the Nagaland region of this ophiolite complex (Figure 10). The ~~samples documented~~ **investigated samples** show considerable microstructural variation, ranging from largely undeformed (N5 and 14) to sheared (11, 3b, 7c, and 13). The contrasting textures and ages of the studied rocks, together with reported metamorphic **recrystallizations** ages in the adjoining ophiolite belts in Myanmar (Shi *et al.* 2008; Yui *et al.* 2013; Liu *et al.* 2016) suggest that the terrain has undergone several metamorphic events. In terms of texture, the blueschist facies rocks (N5 and 14) do not show any obvious preferred orientation ~~The almost intact crystal shapes of the constituent minerals (Fig. 2a) allow us to suggest~~ that they were formed predominantly under near-hydrostatic conditions, without apparent shear deformation. By contrast, the sheared samples record deformation and post-tectonic (annealing) recrystallization, ~~as~~ the constituent minerals display preferred orientation, bending, and curving.

Mineral assemblages in the unsheared samples N5 and 14 constrain peak P – T conditions of subduction-zone metamorphism to ~1.8–2.0 GPa and ~420–560 °C, with the calculated proportions and compositions of major minerals matching observed values at ~1.9 GPa and ~480–520 °C (Figure 6) **(I THINK YOU CAN SIMPLY CONCLUDE THAT THE ESTIMATED P-T CONDITIONS ARE THOSE OF THE BEST-MATCH ASSEMBLAGES, THERE IS NEED TO REPEAT AGAIN WHAT IS THE TOTAL RANGE FOR THE PEAK ASSEMBLAGE, YOU ALREADY DISCUSSED THIS IN THE PREVIOUS SECTION. I THINK YOU SHOULD REPORT THIS TIGHTER RANGE ALSO IN THE OTHER SECTION OF THE PAPER (E.G., ABSTRACT,**

650 **CONCLUSIONS) WHERE YOU MENTION THE RESULTS OF YOUR MODELS**

651 **Done).**

652 By contrast, the observed mineral assemblage in sheared (sample 7c) was calculated to
653 be stable at notably lower P – T conditions of ~0.2–0.6 GPa and ~420–490 °C, with observed
654 and calculated mineral proportions and compositions matching best at ~0.6 GPa and ~470 °C
655 **(AS FOR THE PREVIOUS: YOU CAN SIMPLY REPORT 0.6 GPa AND 470°C**

656 **Done).** The calculated peak metamorphic conditions for the unsheared samples agree with P –
657 T conditions previously reported for the area (Chatterjee and Ghose 2010). **The P – T**
658 **conditions are far-removed from the slab-top range for modern-day subduction reported by**
659 **Syracuse *et al.* (2010). The calculated pressures of ~1.9 GPa for peak metamorphism and**
660 **~0.6 GPa for retrograde equilibration are approximately equivalent to depths of 60 km and 15**
661 **km, respectively, assuming no significant tectonic overpressure.** In Figure 10, the P – T path
662 calculated here is compared with published examples for other blueschist samples from the
663 Naga ophiolites **(NO COMMENT ON THESE? THEY TOOK PRETTY DIFFERENT**
664 **FROM YOURS (ESPECIALLY THE ONE LABELLED AB14), MAYBE YOU CAN**
665 **TRY TO PROPOSE SOME EXPLANATION ABOUT THIS MISMATCH)** and other
666 studies with thermal models of the global active subduction zones (Syracuse *et al.* 2010).

667 The age of the high- P metamorphic event is crucial to the reconstruction of the geological
668 history of this little-known terrain; however, reliable **metamorphic** age data has been lacking,
669 and ages for the Nagaland ophiolite are poorly resolved **whereas it is not so in the Eastern Belt**
670 **(AS SAID IN A PREVIOUS COMMENT, I THINK YOU SHOULD SPEND SOME**
671 **ADDITIONAL WORD ON THIS, OTHERWISE IT IS NOT COMPLETELY CLEAR**
672 **WHY YOU THINK THAT THERE IS SUCH LACK OF RELIABLE AGE DATA**
673 **ADDED).** We have integrated **our** new age and P – T data into a revised tectonic model for the
674 evolution of the Naga ophiolite belt, as shown in Figure 11. Only one whole-rock K–Ar isotopic

age of 148 ± 4 Ma (Upper Jurassic) has been reported from a volcanic rock in this area (Sarkar *et al.* 1996), which is supported by a radiolarian age (Baxter *et al.* 2011), whereas recently, a younger U–Pb zircon age of 115 Ma (Lower Cretaceous) has been reported from a plagiogranite (Singh *et al.* 2017). Based on the available geochronological and radiolarian ages, the formation age of the Nagaland ophiolite crust thus likely ranges between Early Cretaceous (Liu *et al.* 2016; **our** unpublished data) and Late Jurassic (Figure 11a). Past plate reconstructions during this period suggest that early subduction off the coast of Myanmar dipped to the west during the Jurassic, but there was a reversal in polarity immediately prior to the Early Cretaceous (Figure 11b; Bhowmik and Ao, 2015). This reversal caused the proto-Nagaland ophiolite complex oceanic crust to experience subduction along an eastern-dipping convergent margin during the Early Cretaceous, with U–Pb ages of the blueschist associated with the Nagaland ophiolite suggesting that peak high-pressure metamorphism was reached at around this time (Figure 11c).

Utilizing the integrated petrologically constrained *in situ* ages and thermobarometry shows that the unsheared sample 14 yielded a U–Pb age of 95.3 Ma while sheared samples yielded ages ranging between 93.7 Ma (sample 11) and 88.8 Ma (sample 13) Ma, illustrating an age difference between the sheared and unsheared samples. ~~The present study shows~~ **This suggests** that the Mesozoic ophiolite underwent HP–LT subduction-related metamorphism c. 95 Ma and that exhumation was a continuous process that lasted until c. 89 Ma (Figure 11d). This age range is in agreement with the Guillot *et al.* (2008)’s ~~reported~~ HP metamorphic age **inferred from K–Ar whole rock and mineral (phengite, glaucophane)** ages of 100 to 80 Ma **(MAYBE YOU SHOULD ADD SOME DETAIL HOW THIS TIME HAS BEEN ESTIMATED (I.E., IS THIS COMING FROM GEOCHRONOLOGICAL ANALYSES? IF SO, WHAT IS THE METHOD THAT WAS APPLIED? DONE)** for the western Himalayan Tethyan ophiolites. Based on a zircon isotopic study, an older age of

115 Ma has been reported from the garnetiferous amphibolite of the adjoining Myanmar ophiolite (Liu *et al.* 2016). However, no petrological information was presented, making it hard to evaluate the significance of this age. ~~It~~ **As a consequence, it** is unclear whether the available ages (~~Liu *et al.* 2016 and our data~~) record a prolonged emplacement event, discrete metamorphic events or if the older amphibolite represents remnants of metamorphic sole of the ophiolite belt. Although the unsheared sample dataset is within uncertainty of the sheared sample dates, an overall age progression is evident from the studied sheared and unsheared samples. Based on the combined U–Pb age dataset and the calculated P – T regime, it can be inferred that the Nagaland blueschist rocks were exhumed at a rate of ~1 cm/year (~45 km in 5 Ma), which is in the order of rates of plate tectonic processes on the Phanerozoic Earth (**I THINK THIS STATEMENT NEEDS SOME APPROPRIATE SUPPORTING REFERENCE. IN ANY CASE, PLEASE NOTE THAT THIS IS CONTRAST WITH WHAT YOU REPORTED IN THE ABSTRACT, WHERE YOU SAID THAT THIS EXHUMATION IS ‘A TYPICAL SLOW’ (LINE 44). PLEASE CORRECT IN ORDER TO AVOID INCONSISTENCIES CORRECTED).**

U–Pb dating of low-uranium minerals such as calcite, prehnite, epidote, amphibole (**YOU DID NOT SAY YOU MADE U-PB ANALYSES OF SUCH KIND OF MINERALS. SO I AM NOT SURE IT IS APPROPRIATE TO MENTION THESE TOO, IT HAS BEEN MENTIONED**) at small scale is a new and promising geochronological method. In the present study, we focussed on both carbonate and other cogenetic silicate phases **such as prehnite, epidote, amphibole etc. (SO YOU ACTUALLY PERFORMED U-PB DATINGS ALSO ON OTHER PHASES? IF SO, WHY YOU DIDN'T REPORT THIS IN THE U-PB GEOCHRONOLOGY SECTION? THIS IS GETTING REALLY CONFUSING, I WARMLY INVITE YOU TO ELUCIDATE AND MAKE IT EXTREMELY CLEAR THROUGHOUT THE MANUSCRIPT. DONE)**

formed at the same time and the isotopic systems seem to be closed since the metamorphic event. The reported age uncertainty could be improved by using well characterised specific with less scatter age and matrix matched standards (e.g., carbonate minerals normalisation of Pb–Pb isotope is currently achieved using a synthetic glass other than a carbonate, Roberts et al. 2020) standards-improved reference materials (both carbonate and silicate phases) (WHAT DO MEAN BY THIS? IN WHAT SENSE THESE REFERENCE MATERIALS SHOULD BE IMPROVED? I THINK SOME ELUCIDATION MIGHT BE USEFUL, DONE) Although the behaviour of uranium in carbonates that have undergone high *P*/low *T* is not clear because of the lack of studies in natural and synthetic systems, our study shows suggest that the U–Pb systematics of carbonate can withstand temperatures up to 500 °C without resetting. These data thus encourage the ongoing development of in-situ dating of carbonates and low uranium silicate minerals as a tool to understand the rates and ages of tectonic processes.

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Figure captions

Figure 1. (A) Regional geological map of Indo-Myanmar Range and part of Myanmar (after Acharyya 2015). (B) Geological map of the Indo-Myanmar ophiolite belt (after Geological Survey of India M.N.C. DRG No. 42/87) (C) Geological map of the Nagaland ophiolite belt showing sample locations (after Anon. 1986, Ao and Bhowmick, 2016). (D) Field photographs (1) Unfoliated/Unsheared sample occur as boulders. Person for reference. (2) Unsheared sample showing the slicken sided face, chisel is for reference. (3) Blueschist samples present as blocky boulders. (4) Sheared sample showing foliation on a freshly broken face. Pen shows the foliation trend.

Figure 2. Thin-section photomicrographs showing representative mineral assemblages and microstructures for undeformed samples N5 (a–b) and 14 (c–d). All thin section images are shown under plane-polarized light. Scale bar is 1 mm. (a–b) Glaucophane- and epidote-rich matrix in sample N5, with minor garnet porphyroblasts associated with quartz and muscovite. (c) Small millimetre-scale garnet in sample 14 mostly occurs in quartz-rich domains that are relatively epidote- and barroisite-poor. (d) Barroisite grains enclose epidote crystals. Mineral use in 2(a) Gln – Glaucophane, Grt – Garnet, Ep – Epidote, Ms – Muscovite. 2(b) Gln – Glaucophane, Grt – Garnet, Ep – Epidote, Ms – Muscovite, Qtz – quartz, 2(c) Brs –

966 Barroisite, Carb – Carbonate, Grt – Garnet, Ep – Epidote. 2(d) Brs – Barroisite, Ep – Epidote,
967 Ms – Muscovite, Qtz – quartz, Ttn – Titanite.

968

969 Figure 3. Thin-section photomicrographs showing representative mineral assemblages and
970 microstructures in sheared samples 7c (a–b) and 11 (c–f). All thin section images are shown
971 under plane-polarized light (unless stated otherwise) and oriented perpendicular to the
972 dominant metamorphic foliation. Scale bar is 1 mm. (a) The metamorphic foliation in sample
973 7c is defined by aligned crystals of epidote, sodic-calcic amphibole, and calcic amphibole, (b)
974 and is crosscut by quartz- and carbonate-filled veins that also cause localized deflections at
975 their intersections. Sample 11 contains olive-green aegirine–augite (c) and garnet (d)
976 porphyroblasts that are wrapped by a glaucophane–magnesioriebeckite foliation defined by
977 alternating glaucophane- and quartz-rich bands. Sheared veins filled with carbonate (e) and
978 quartz (f) exhibit ductile deformation microstructures and dynamic recrystallization. Mineral
979 abbreviation use in Figure 3(a) Brs – Wnc: Barroisite – Winchite, Ep – Epidote, Prg – Ed:
980 Pargsite – Edinite, Ttn: Titanite, Figure 3(b) Qtz – Quartz, Carb – Carbonate, Brs –
981 Barroisite, Wnc – Winchite, Ep – Epidote, Ms – Muscovite, Kfs – K-feldspar, Ab – Albite,
982 3(c) Agt – Aegirine augite, Gln: Glaucophane, Fgl – Ferroglaucophane, Grt – Garnet, Qtz –
983 Quartz, Ms – Muscovite, Figure 3(d) Alb – Albite, Carb – Carbonate, Gln – Glaucophane,
984 Fgl – Ferroglaucophane, Quartz – Quartz, Figure 3(e) Carb – Carbonate, Ms – Muscovite,
985 Qtz – Quartz, Figure 3(f) Carb – Carbonate, Qtz – Quartz.

986

987 Figure 4. Garnet compositional line profile for sample N5, running from rim to rim across a
988 representative-sized euhedral grain (~0.75 mm diameter). (a) Cation mole fractions of
989 divalent cations. (b) X-ray compositional map of divalent cations showing relative

concentrations from core to rim. Colours do not represent equivalent cation concentrations between images.

Figure 5. Compositions of amphiboles from all studied samples, categorized according to the classification scheme of Hawthorne *et al.* (2012). Discrimination between calcic (group 2), calcic-sodic (group 3), and sodic (group 4) amphiboles is based upon the Na content of the M4 crystallographic site, with the ranges <0.5 , $0.5\text{--}1.5$, and >1.5 , respectively for a 23-oxygen recalculation. Representative compositions are given in Table 2.

Figure 6. Results of mineral equilibria modelling for sample N5. (a) Pressure–temperature (P – T) pseudosection constructed for the bulk composition given in Table 3. Dotted overlay represents the global range of P – T conditions modelled to occur at the surface of subducting ocean crust in present-day subduction zones (Syracuse *et al.* 2010). Gray star and associated dashed ellipses represent the results of avPT calculations (Table 4) and are shown at 1 and 2 S.D. Bold line marks the extent of H_2O -bearing assemblage fields. Numbered fields are as follows: 1 – Grt Ms Cld Tlc Omp, 2 – Grt Ms Cld Tlc Omp Gln, 3 – Grt Ms Cld Tlc Omp Gln Lws, 4 – Grt Ms Cld Tlc Omp Ky Lws, 5 – Grt Ms Act Cld Tlc Ky Lws, 6 – Grt Ms Bt Cld Act Gln, 7 – Grt Chl Bt Cld Act Gln, 8 – Grt Bt Act Gln Mag, 9 – Grt Bt Chl Hbl Gln, 10 – Bt Omp Hbl Pl H_2O , 11 – Bt Omp Hbl Pl Ab H_2O , 12 – Grt Ms Omp Hbl H_2O , 13 – Grt Ms Gln H_2O , 14 – Grt Chl Ms Omp Gln, 15 – Grt Chl Ms Brs Gln, 16 – Grt Chl Ms Omp Gln Lws, 17 – Grt Ms Cld Omp Gln Lws. Some small, minor fields are unlabelled for clarity. (b) Interpreted peak assemblage field showing isolines of molar proportions of selected phases. Dashed line labelled $\text{XNaM}_4\text{Act} = 0.25$ marks the division between actinolite (<0.25) at low- T and barrosite (>0.25) at high- T . (c) Bar chart showing degree of correlation between observed volume proportions (%) of minerals and calculated proportions at 1.9 GPa and 485

°C (red star in part b). (d) Graphical representation of the calculated (Calc. vol.%) and
 observed (Obs. Vol%) volume proportions for sample N5 at 1.9 GPa and 485 °C.
 Figure 7. Results of mineral equilibria modelling for sample 14. (a) Pressure–temperature (P – T) pseudosection constructed for the bulk composition given in Table 3. Dotted overlay
 represents the global range of P – T conditions modelled to occur at the surface of subducting
 ocean crust in present-day subduction zones (Syracuse *et al.* 2010). Gray star and associated
 dashed ellipses represent the results of avPT calculations (Table 4) and are shown at 1 and 2
 S.D. Bold line marks the extent of H₂O-bearing assemblage fields. Numbered fields are as
 follows: 1 – Grt Ms Pg Omp Act Gln, 2 – Grt Ms Bt Omp Act Gln, 3 – Grt Bt Omp Act Gln
 Ab, 4 – Grt Bt Omp Act Gln Ilm Mag Ab (–Rt), 5 – Grt Bt Omp Act Gln Mag Ab (–Rt), 6 –
 Grt Bt Omp Brs Gln Mag, 7 – Bt Omp Brs Gln Hbl Mag, 8 – Grt Bt Omp Brs Hbl, 9 – Bt Di
 Brs Hbl H₂O, 10 – Bt Di Hbl Ttn H₂O (–Rt), 11 – Bt Di Hbl, 12 – Grt Ms Bt Omp Act H₂O,
 13 – Grt Ms Tlc Omp Act H₂O, 14 – Grt Ms Tlc Omp H₂O, 15 – Grt Ms Tlc Omp Brs Lws,
 16 – Grt Chl Ms Omp Brs, 17 – GrtChl Ms Omp Brs H₂O. Some small, minor fields are
 unlabelled for clarity. (b) Interpreted peak assemblage field showing isolines of molar
 proportions of selected phases. Dashed line labelled $X_{\text{NaM}_4\text{Act}} = 0.25$ marks the division
 between actinolite (<0.25) at low- T and barroisite (>0.25) at high- T . (c) Bar chart showing
 degree of correlation between observed volume proportions (%) of minerals and calculated
 proportions at 2.0 GPa and 525 °C (red star in part b). (d) Graphical representation of the
 calculated (Calc. vol.%) and observed (Obs. Vol%) volume proportions for sample 14 at 2.0
 GPa and 525 °C.

Figure 8. Results of phase equilibria modelling for sample 7c. (a) Pressure–temperature (P – T)
 pseudosection constructed for the bulk composition given in Table 3. Dotted overlay
 represents the global range of P – T conditions modelled to occur at the surface of subducting

ocean crust in present-day subduction zones (Syracuse *et al.* 2010). Gray star and associated dashed ellipses represent the results of avPT calculations (Table 4) and are shown at 1 and 2 S.D. Bold line marks the extent of H₂O-bearing assemblage fields. Numbered fields are as follows: 1 – Omp Act Gln Mag Rt Hem (–Ttn), 2 – Omp Act Gln Mag Rt, 3 – Omp Act Gln Mag, 4 – Omp Act Gln Mag Ab, 5 – Act Gln Mag Ab, 6 – Omp Act Hbl Gln Mag Rt (–Ttn), 7 – Omp Act Hbl Gln Ab, 8 – Act Hbl Gln Mag Ab, 9 – Chl Act Hbl Mag Ab, 10 – Chl Act Hbl Ab H₂O, 11 – BrsHbl Ab, 12 – Omp Act Hbl Ab, 13 – Di Act Hbl Ab H₂O, 14 – Di Hbl Ab H₂O, 15 – Di Act Hbl Pl, 16 – Di Hbl Pl Mag Hem (–Ttn, Ep), 17 – Omp Act Hbl Gln Rt Hem (–Ttn), 18 – Omp Brs Hbl Gln Rt Hem (–Ttn), 19 – Omp Brs Hbl Gln Rt (–Ttn), 20 – Omp Act Hbl Gln Rt (–Ttn), 21 – Omp Brs Hbl Gln, 22 – Omp Act Hbl Gln, 23 – Omp Brs Gln Rt Hem (–Ttn), 24 – Omp Act Hem (–Ttn), 25 – Omp Act (–Ttn). Some small, minor fields are unlabelled for clarity. (b) Interpreted peak assemblage field showing isolines of molar proportions of selected phases. Dashed line labelled $X_{\text{NaM}_4\text{Act}} = 0.25$ marks the division between actinolite (<0.25) at low-T and barrosite (>0.25) at high-T. (c) Bar chart showing degree of correlation between observed volume proportions (%) of minerals and calculated proportions at 0.6 GPa and 465 °C (red star in part b). (d) Graphical representation of the calculated (Calc. vol.%) and observed (Obs. Vol%) volume proportions at 0.6 GPa and 465 °C.

Figure 9. Isochrons for all dated samples. A: Unsheared sample 14. B: Sheared sample 11. C: Sheared sample 3b. D: Sheared sample 13. All ellipses are shown at the 2σ confidence interval and n = number of analyses.

Figure 10. Pressure–temperature–time (*P–T–t*) diagram summarizing the history of blueschist-facies rocks from the Nagaland ophiolite complex. Red boxes represent calculated

conditions of metamorphism and thick grey arrow represents the interpreted P – T – t evolution. Paths for Nagaland blueschists reported by Chatterjee and Ghose (2010) and Ao and Bhowmik (2014) are shown (CG10 and AB14, respectively) for comparison. Aragonite-calcite stability curve is from Johannes and Puhon (1971).

Figure 11. Schematic tectonic model for formation and exhumation of the Nagaland ophiolite belt and its metamorphic suite. Final tectonic configuration of tectonostratigraphic slices is modified after Khogenkumar et al. (2020). (a) Westward-dipping subduction away from Myanmar during the Jurassic, with future Nagaland ophiolite belt oceanic crust on the overlying plate. (b) Reversal in the subduction dip direction prior to the Early Cretaceous, leading to burial of future Nagaland ophiolitic crust and mantle. (c) Peak metamorphism of the studied samples was achieved during the Middle Cretaceous, with (d) slab breakaway and buoyancy-driven exhumation and associated shearing of these units during the Middle to Late Cretaceous. (e) the final configuration of the Indo-Myanmar plates and suture zone between following collisional orogenesis. Yellow star indicates locations of the studied samples during metamorphism and deformation.