

PS Evaluation Method for Hydrocarbon Cleaning Effect in Kerogen-Rich Gas Shale*

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Abstract

Researchers have strived for years to study the rock properties of gas shale, but little attention has been paid to the cleaning effect of the hydrocarbon. Lack of proper evaluation criterions for the cleaning effect makes it hard to prove the reliability of rock physics parameters, such as porosity, permeability and electrical parameters etc. In rocks with no organic matter (i.e. sandstone), the cleaning usually aims to remove all hydrocarbons. However, some organic matter compounds in gas shale have fluid and solid dual characteristics. A proper core cleaning for it should be able to remove all the fluid but keep the solid organic matter as it is classified as a part of the matrix. Consequently, the evaluation method for gas shale needs to be able to clear the integrity of solid organic matter matrix. The recently proposed Rock-Eval II pyrolysis evaluation method, which can discern the solid and fluid organic matters in gas shale and give a visual reflection of hydrocarbon cleaning effect, solves the problems in fluorescence detection methods. However, researches indicate that the program from this progressive pyrolysis method has problems in differentiating free hydrocarbons and organic matter components in kerogen-rich gas shale. It provides an insufficient cleaning result because a portion of fluid-like hydrocarbon residue (FHR, which naturally considered as free hydrocarbon) might be inappropriately classified as the solid organic matter matrix. Therefore, the ESH (Extended Slow Heating) pyrolysis evaluation method is proposed to evaluate the hydrocarbon cleaning effect in kerogen-rich gas shale. The ESH pyrolysis technique solves those problems in Rock-Eval II cycle by providing sufficient pyrolysis time, lower heating rate and lower initial temperature. The ESH program divides the hydrocarbon into three finer fractions: S1E, light free hydrocarbon; S2aE, FHR; and S2bE, solid organic matter. The completion of hydrocarbon cleaning is evaluated by comparing the differences between ESH programs measured on the uncleaned and cleaned aliquots. The evaluation criterions for the complete cleaning are expressed as the disappearance of S1E and S2aE fractions and the invariant of S2bE fraction on the cleaned sample's ESH program. The experimental results show that the ESH program is more reasonable in evaluating the free hydrocarbon cleaning level and the integrity of solid organic matter in kerogen-rich gas shale contrast to the Rock-Eval II program.



Evaluation method for hydrocarbon cleaning effect in kerogen-rich gas shale

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Introduction

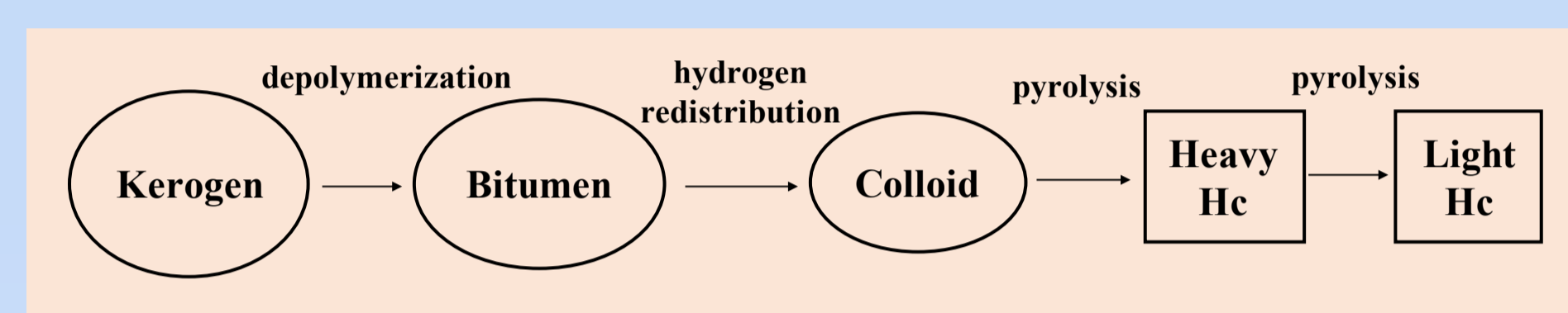
Cleaning of hydrocarbons should be done prior to most tests conducted to investigate rock properties. Due to the co-existence of fluid and solid hydrocarbons in gas shale, the cleaning components in it is quite different to that in the rocks without organic matter. It is more than a work to clean all hydrocarbons simply. A proper cleaning should remove all fluid and fluid-like hydrocarbons (parts of the pore fluid), but not alter the solid organic matter as it is a part of the matrix.

Lack of proper evaluation criteria for the cleaning effect makes it hard to prove the reliability of the results. A general evaluation method for the cleaning effect of hydrocarbons in gas shale is needed, which must able to discern the fluid from solid hydrocarbons clearly and tell the integrity of solid organic matrix.

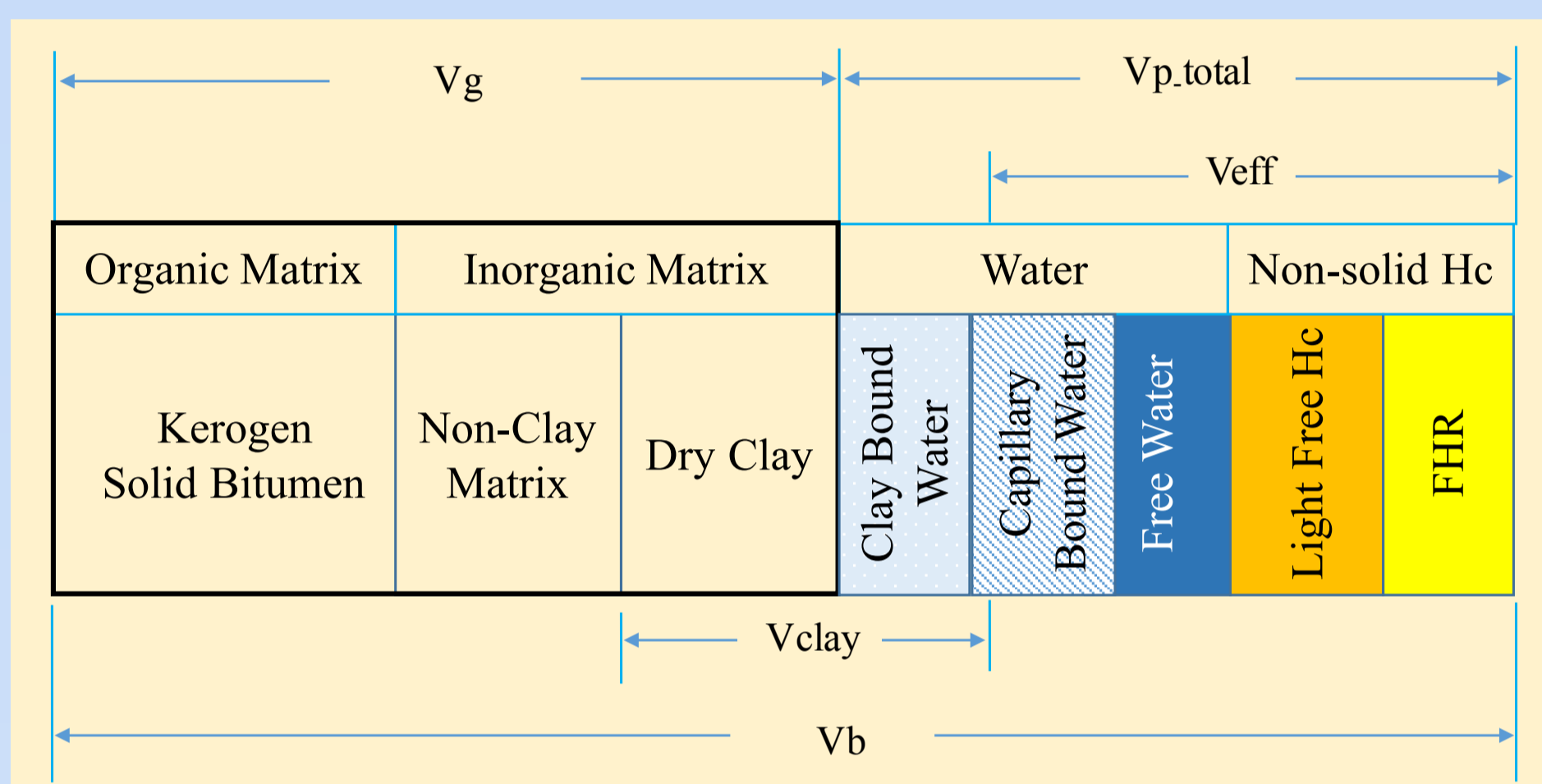
1. Components model

Organic matter (OM) in gas shale is a mixture of different organic compounds that have different rheological properties.

gaseous, liquid and solid hc



Evolution of kerogen



Components model of gas shale

Aims: remove all the non-solid hc (free hc) but not alter the solid organic matrix.

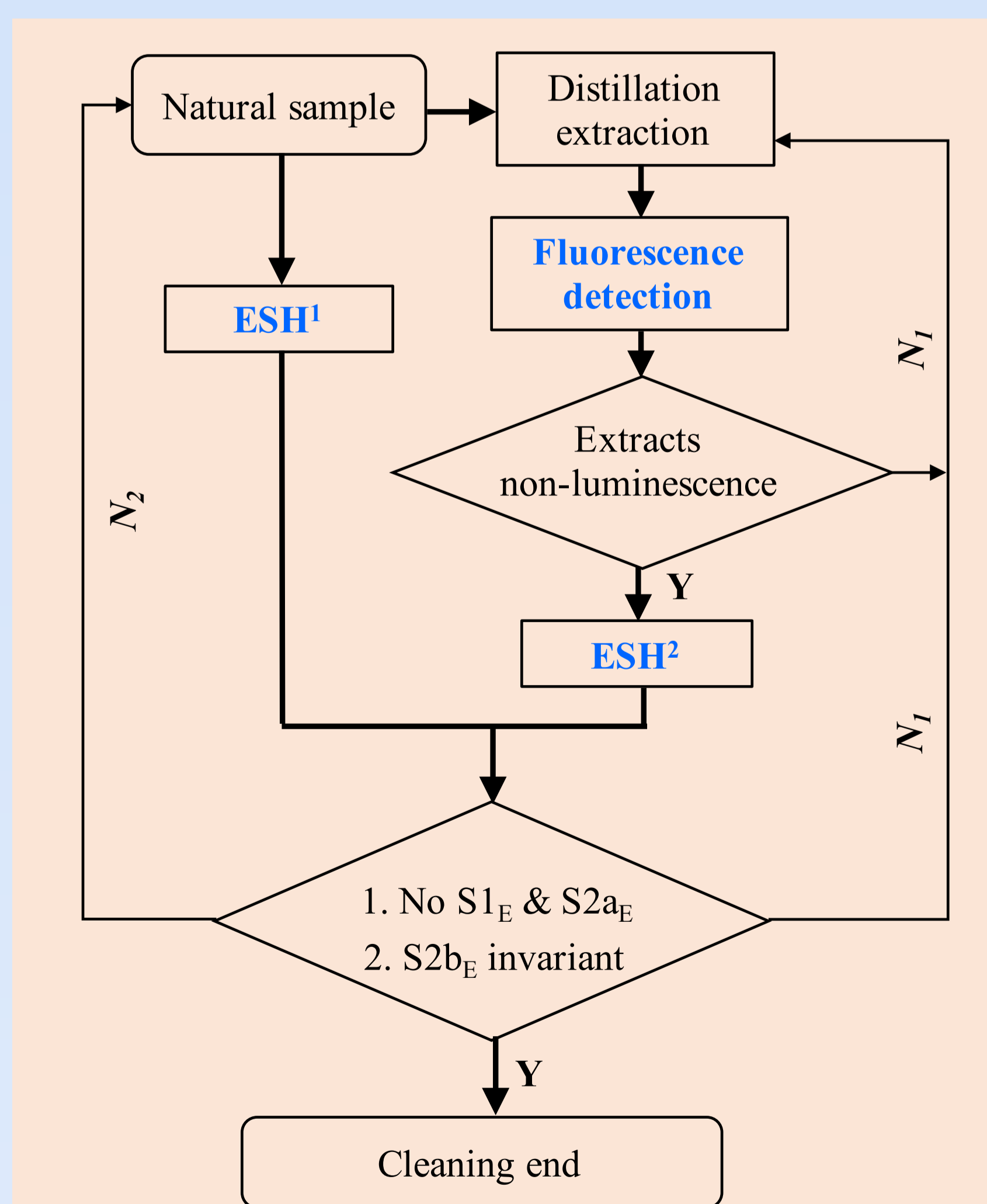
Non-solid Hc: light free hc ($S1_E$) and FHR ($S2a_E$)

*Light free hydrocarbon, including light oil and gas condensates.

*FHR, fluid-like hc residues, are higher molecular (moderate to heavy) free hydrocarbons and occurs as a film of condensed, heavy hydrocarbon residues coating the surfaces of the intergranular pores.

Organic matrix: kerogen and solid bitumen ($S2b_E$)

2. Flow Chart



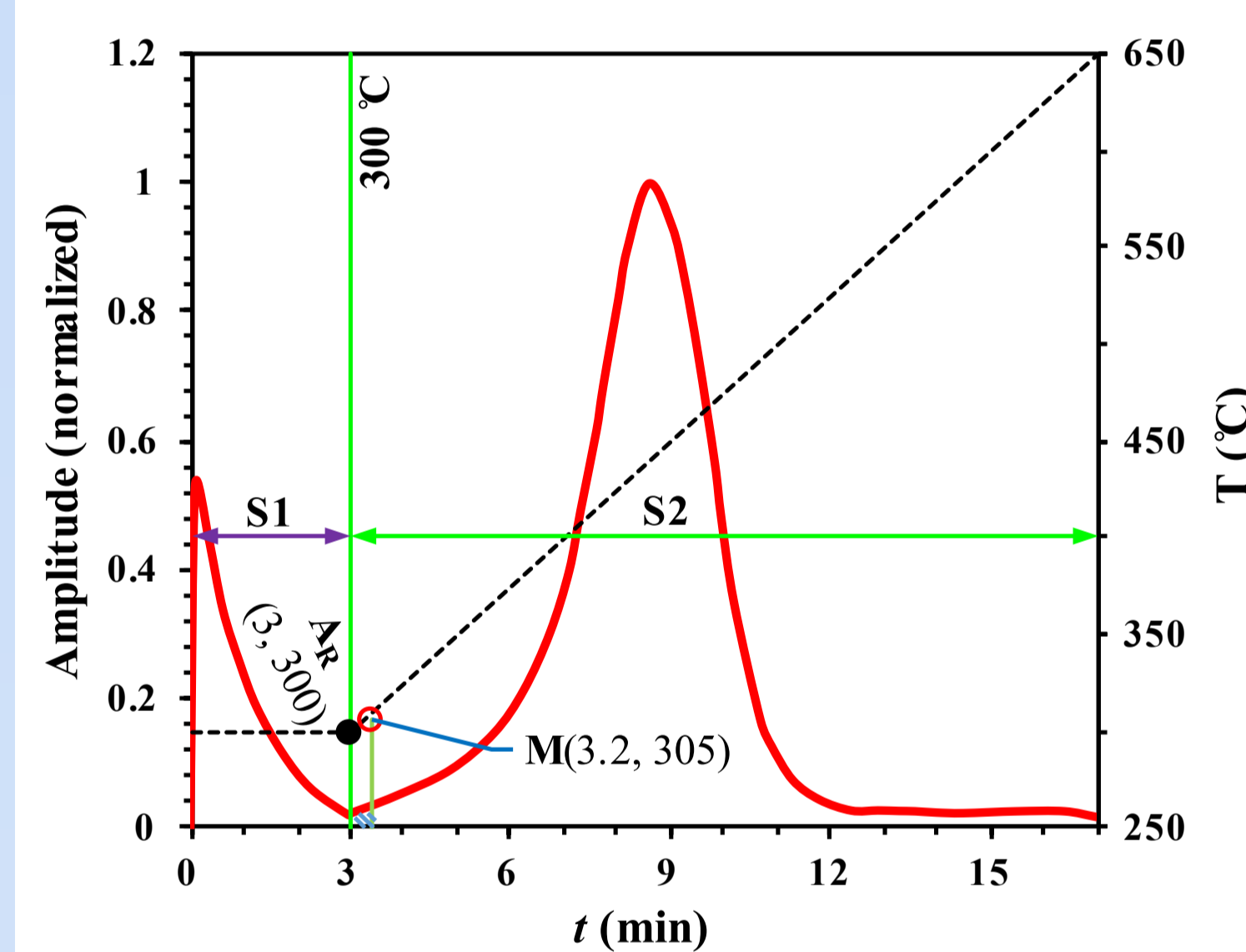
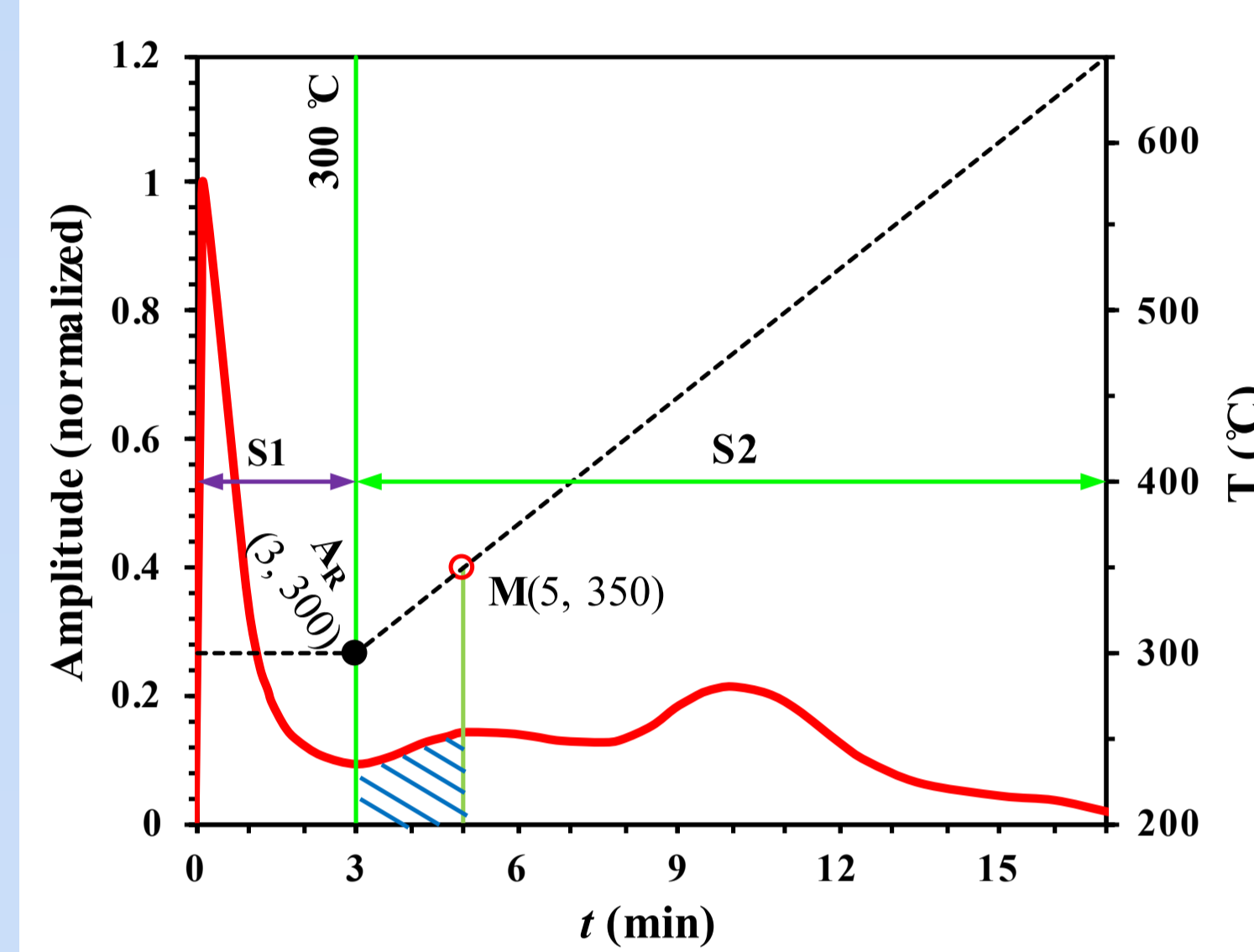
Method:

Compare the ESH pyrograms measured on the uncleaned and cleaned aliquots.

The **fluorescent detection** is applied to make a prejudgement for the cleaning result.

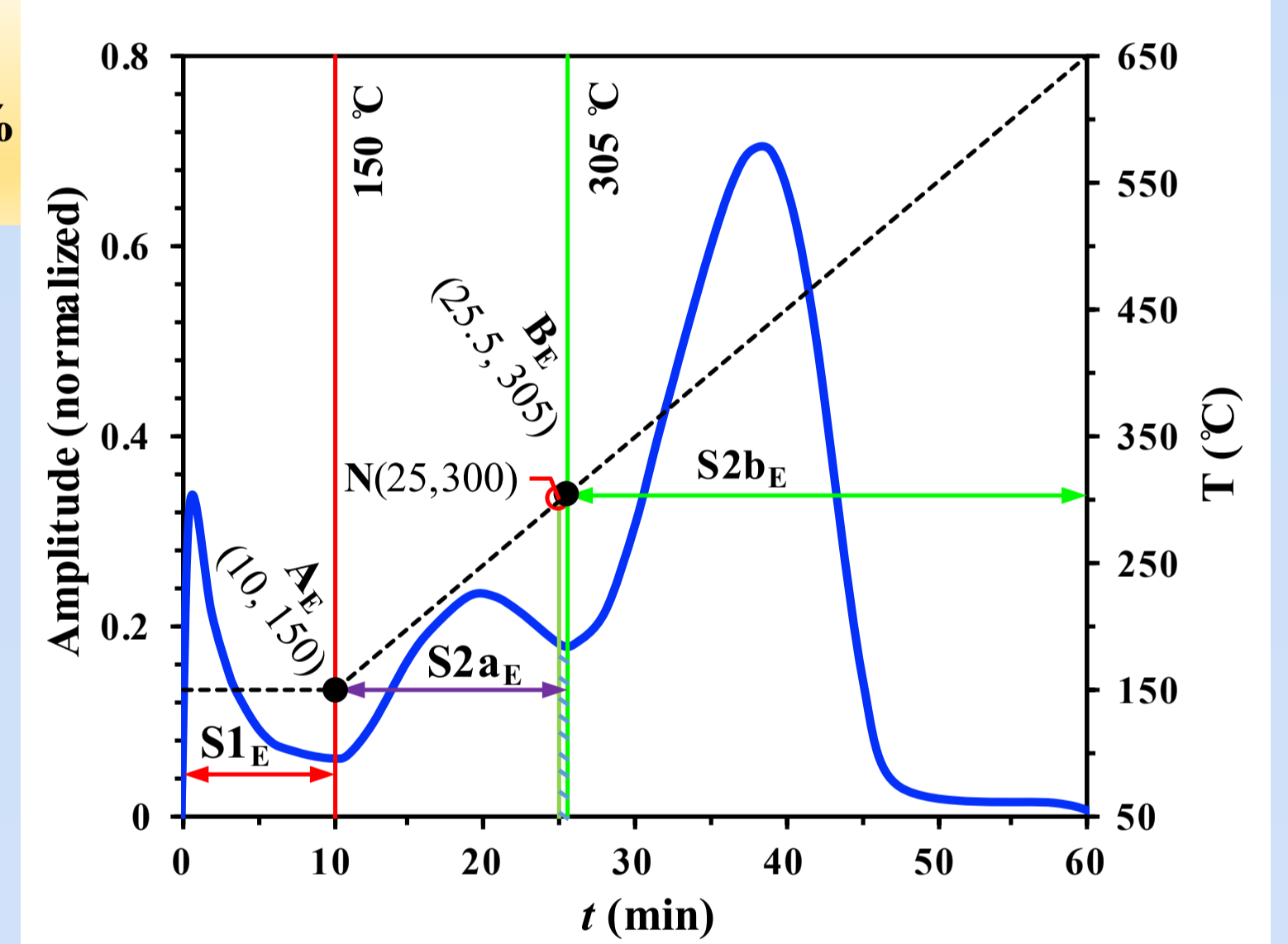
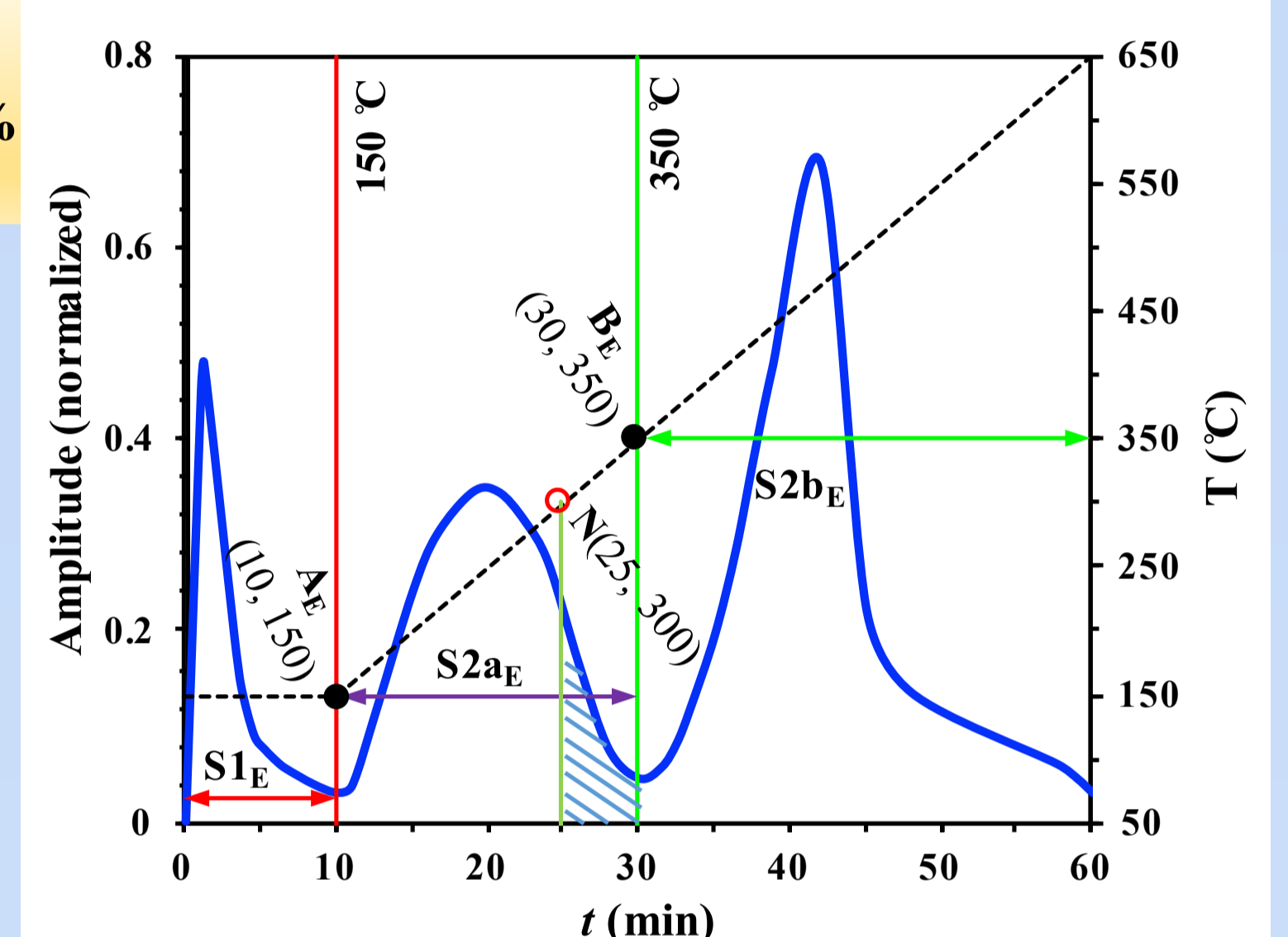
3. Pyrogram Characteristics and Differences

Rock Eval II pyrogram conventional



S1: free Hc, <300°C
S2: solid OM, >300°C

ESH pyrogram modified

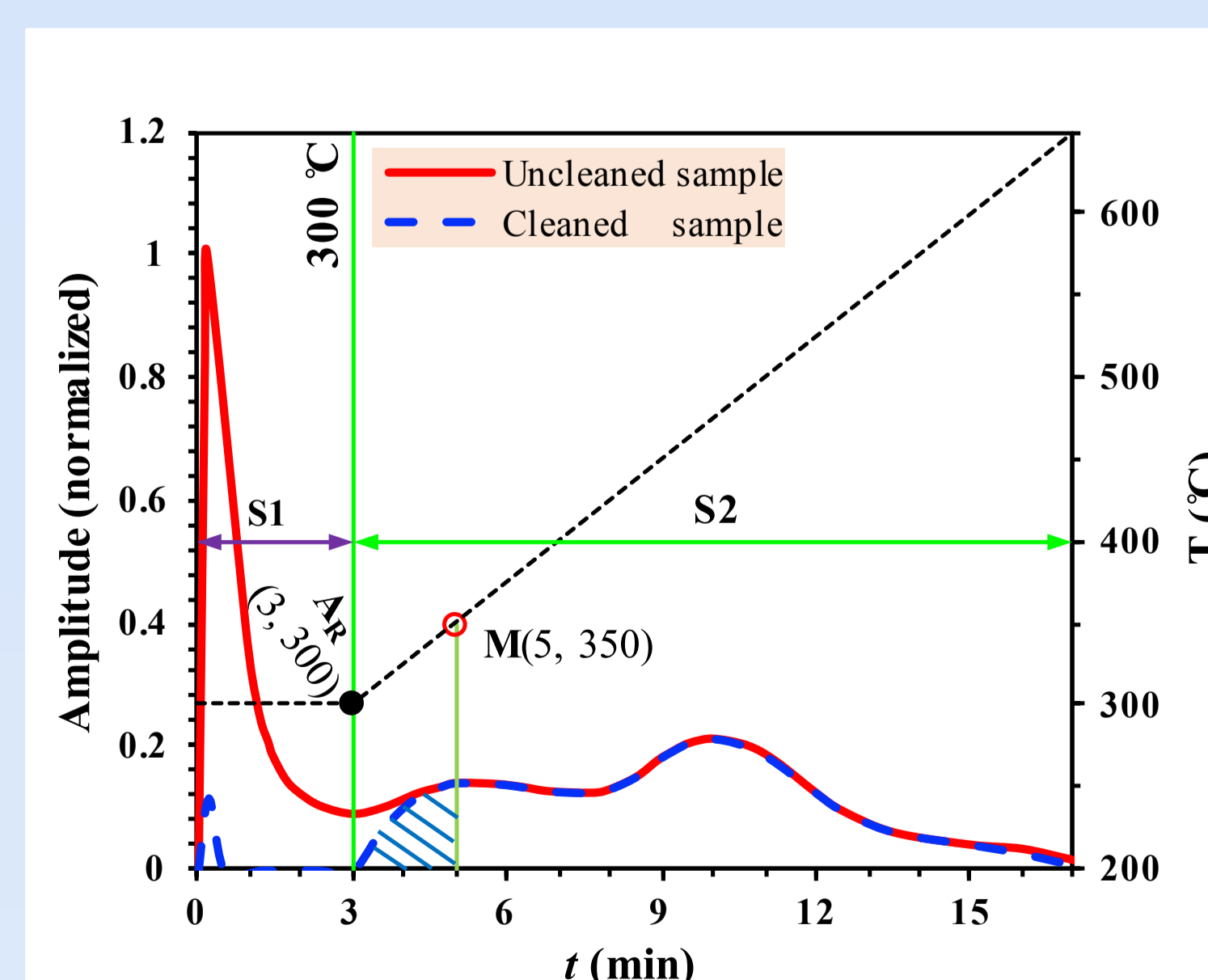


S1_E, light free hc, <150°C;
S2a_E, FHR, 150°C - B_E
S2b_E, solid OM, >B_E

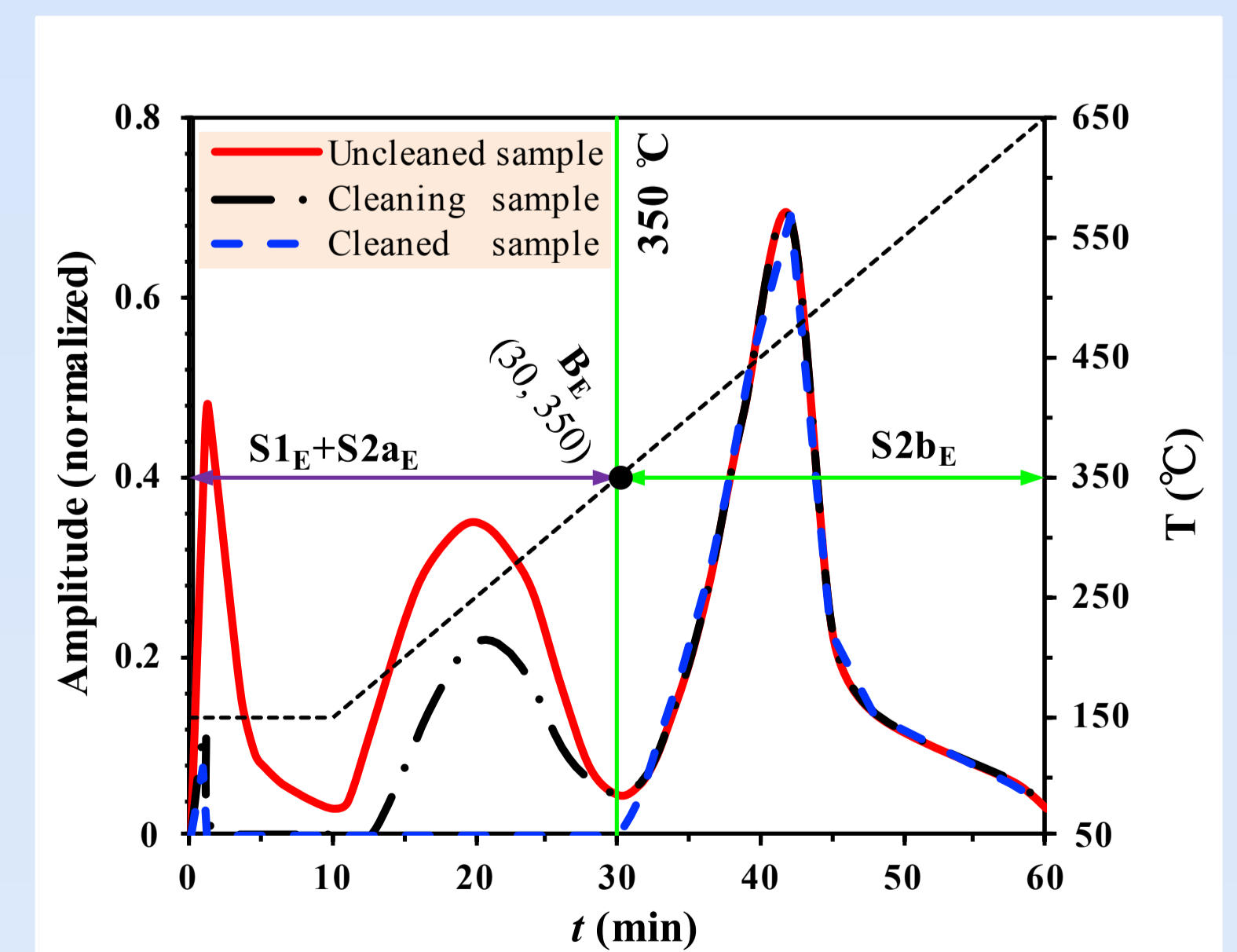
Shaded region A_R-M on the Rock-Eval II pyrogram, which has the same pyrolysis temperature ranges with B_E-N on the ESH pyrogram, is regarded as the solid OM **incorrectly**. It takes about 1%-6% volume of the pore space.

4. Evaluation Criteria

Rock Eval II



ESH



(1) **Cleaning is completed** if S1_E and S2a_E disappear (except the residue solvent peak) and S2b_E is almost invariant on the cleaned sample's ESH pyrogram.

(2) **Continue to clean** (follow N₁) if some S2a_E remnants are detected.

(3) **Cleaning failed** if S2b_E fraction shows obvious absence (follow N₂).